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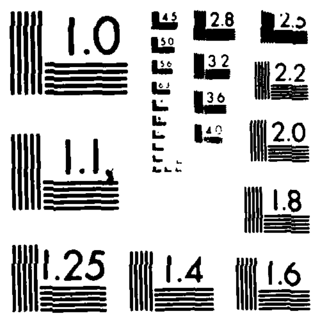

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ELASTIC-PLASTIC FRACTURE TOUGHNESS
TESTING METHODS

by

Wayne Kurt Tritchler

December 1983

Thesis Advisor: K. D. Challenger

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A142 033
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) ELASTIC-PLASTIC FRACTURE TOUGHNESS TESTING METHODS	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis December 1983
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wayne Kurt Tritchler	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	12. REPORT DATE December 1983
	13. NUMBER OF PAGES 112
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Elastic-plastic fracture toughness, fracture toughness, J_{Ic}, J-Integral test, computerized J_{Ic} test

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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S/N 0102-LF-014-6601

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Elastic-plastic fracture toughness

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Elastic-Plastic Fracture Toughness Testing Methods

by

Wayne Kurt Tritchler
Lieutenant Commander, United States Navy
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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
December 1983

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ABSTRACT

An interactive computerized experimental procedure is presented for obtaining the elastic-plastic fracture toughness (J_{Ic}) for a material. The process employs a bend type, single specimen approach by using the measured unloading crack opening displacement (COD) compliance to obtain the crack length. Data are taken, manipulated and plotted during the test to provide the operator with the necessary information to control the testing machine. The program automatically plots the J versus crack extension curve and determines J_{Ic} upon completion of the test. A second program is presented to assist the operator in fatigue precracking the specimen. A third program is used to recall, list and plot the data that were stored on diskette during the test.

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ACKNOWLEDGMENT

I wish to express my sincere appreaciation to my thesis advisor, Dr. Ken Challenger, for his patience and assistance with this work; to Mr. Michael Vassilaros and Mr. Ed Hackett of David Taylor Naval Research and Developement Center for their technical advice and Mr. Ken Ellison for sharing his experience with the equipment.

I dedicate this work to my wife Barbara and sons, Victor and Michael. While they may not understand this work they have provided the encouragement and support required to complete it.

I. INTRODUCTION

A. GENERAL

The toughness of a material is a measure of the energy per unit volume required to cause fracture. It can be quantified by simply taking the area under the true stress strain curve from a simple tension test [Ref. 1]. The practical usefulness of this measurement is limited however, because it provides no information on the material's ability to resist crack propagation. Since all real structures contain notches or cracks of some sort, by design or otherwise, which act as stress concentrators, another measurement of toughness was developed called fracture toughness.

The fracture toughness (K_C) of a material is a measure of the resistance of the material to fracture in the presence of a defect. K is defined as the plane strain fracture toughness and is used to quantify a material's resistance to crack propagation [Ref. 2]. The American Society for Testing and Materials (ASTM) developed Standard E399-83 [Ref. 3] which establishes precise details for accepted testing procedures. The standard also provides rigid criteria for the specimen size and geometry to ensure plane strain conditions exist at the tip of the crack.

The J-integral method, developed by Rice in 1968, provides a means of including plastic deformation at the crack tip [Ref. 4]. J is a measure of the intensity of the entire elastic-plastic stress-strain field that surrounds the crack tip. J_{Ic} is defined as the value of J at the onset of cracking. J-integral testing has gained acceptance as a valuable means of evaluating a metallic material's resistance to crack initiation as demonstrated by establishment of ASTM Standard E813-81 [Ref. [illegible]] The measured value of J_{Ic} has practical applications in measuring the effects of metallurgical variables, heat treatments, and weldments and is being used by researchers today to make such quantitative distinctions [Ref. 5-7].

B. J_{Ic} VERSUS K_{Ic} TESTING

The procedures established by ASTM Standard E399-83 for obtaining K_{Ic} impose minimum specimen size requirements that cause difficulty when testing materials that possess high toughness. The specimen thickness must be sufficient to cause plane strain conditions to exist [Ref. 3]. Hertzberg [Ref. 2] presents the empirical equation developed by Brown and Srawley [Ref. 8]:

$$t \text{ and } a > 2.5 * (K_{Ic}/Ys)$$

where

t = specimen thickness

a = crack length

K_{Ic} = plane strain fracture toughness

Ys = yield strength

A similar analysis for J-integral test specimens reveals that:

$$b \text{ or } B > 25 * (J_{Ic}/Fs)$$

where

b = initial uncracked ligament

B = specimen thickness

J_{Ic} = anticipated value if J_{Ic} recheck when test is completed

Fs = flow stress [(Ys+Uts)/2]

Hertzberg takes this result one step further by showing that J_{Ic} equals $(K_{Ic})^2/E$ (where E equals the material's elastic modulus) for J_{Ic}. By dividing the two equations one sees that:

$$(K_{Ic} \text{ specimen size}) > 20 * (J_{Ic} \text{ specimen size})$$

thus, because the J-integral allows plastic deformation, one of its most significant advantages is that a satisfactory specimen can be obtained at one-twentieth (1/20) of the thickness of a K_{Ic} specimen. This not only means smaller specimens may be used but, also, smaller testing machines are required and therefore costs are reduced. [Ref. 2]

Although J_{Ic} and K_{Ic} provide a different measure of toughness, J_{Ic} can be used to estimate K_{Ic}. ASTM Standard

E813-81 [Ref. 5] provides limited guidelines on the relationship between the two.

C. PURPOSE AND SCOPE OF RESEARCH

The purpose of this thesis is to develop the procedures required to obtain J_{Ic} from J-integral test results using equipment currently available within the Materials Science group of the Mechanical Engineering Department at the Naval Postgraduate School (NPS). A list of the major equipment follows:

a. Series 810 MTS machine

b. HP-9826 computer with internal disk drive and 320K random access memory

c. HP-3497A data acquisition system

d. HP-3437A voltmeter

e. HP-2671G thermal printer

f. HP-7225B graphics plotter

Figure 1 shows the system layout.

The test method developed is to comply with ASTM Standard E813-81 [Ref. 5], be easy for others to use, and require a minimum of operator interaction. It is specifically designed for use with three point bend specimens using a single vice multiple specimen approach. The method developed and presented here covers the entire test, including specimen preparation, precracking, testing, and validation of results.

II. NATURE OF THE PROBLEM

A. J-INTEGRAL

The J-integral is a mathematical expression used to characterize the near tip stress-strain environment of cracked elastic-plastic bodies [Ref. 9]. It is a path independent line integral that surrounds the crack tip for non-linear plastic metallic materials [Ref.5]. The equation delveloped by Rice is [Ref. 4]:

$$J = \int_{\Gamma} (W\, dy - T \cdot (\partial u/\partial x)\, ds)$$

where

- W = loading work per unit volume, or for elastic bodies, strain energy
- Γ = the path of the integral, which encloses the crack tip
- ds = increment of the contour path
- T = outward traction vector on ds
- u = displacement vector at ds
- x,y,z = rectangular coordinates
- $T \cdot (\partial u/\partial x)ds$ = the rate of work input from the stress field into the area enclosed by Γ.

Figure 2 provides a pictorial representation of this equation.

The mathematical expression developed by Rice [Ref. 4] has been manipulated and reduced to simpler forms for

specific specimen geometries. Rice, Paris, and Merkel [Ref. 10] reduced the J-integral expression for a three point bend specimen to:

$$J = \frac{2 * A}{b * B}$$

where

J = resistance to crack initiation

A = area under load versus load line displacement curve

b = uncracked ligament

B = specimen thickness

This thesis is not intended to redevelop the J-integral but rather apply it, therefore only the result is presented here.

More recent work by Ernst, Paris, and Landes [Ref. 11] corrects the calculation of J due to crack growth by means of the following equation:

$$J_{(i+1)} = (J_i + (n/b)_i * A_{i,i+1}) * (1 - (Y/b) * (a_{i+1} - a_i))$$

where

$J_{(i+1)}$ = current value of J

J_i = last J computed

n = 1 for three point bend type specimens

$A_{i,i+1}$ = area enclosed by the actual test record and lines of constant displacement d_i and d_{i+1}

Y = 1 for three point bend type specimens

b = current uncracked ligament

W = specimen width

a_i = last crack length

a_{i+1} = current crack length

Correcting for crack growth during the test is necessary when using a single specimen approach as used by this method.

The blunting line defined as:

$$J = 2 * Fs * delta\_a$$

where

Fs = flow stress

delta_ a = change in crack length

approximates apparent crack advance due to crack tip blunting in the absence of slow-stable crack tearing. It is plotted on the J versus crack extension plot. A linear regression fit through the applicable data points is then plotted. The intersection of the two lines is by definition J_{Ic} (see Figure 3).[Ref. 5]

B. PREVIOUS WORK

The early experimental methods used to obtain J_{Ic} required the preparation of several specimens. Each specimen received a different load. The specimens were then heat tinted (to identify crack length) and broken apart. Each specimen provided one data point on the J versus crack extension curve, commonly referred to as the J-R curve [Ref.

9 and 11]. Checks were then performed on the validity of the data. A minimum of four valid data points were required to obtain a linear least squares fit and hence J_{Ic} [Ref. 5,10 and 12].

Researchers over the last five years have developed a much improved test method whereby a single specimen can be used. Today's computerized data acquisition equipment and data manipulation are ideally suited for the task. By relating the compliance (how much a specimen bends under a given load) to the crack length, all the data required to obtain the J-R curve can be collected by using a single specimen [Ref.11-16]. Clarke [Ref.16] states that prior to the use of computers the time required for data reduction to obtain the J-R curve was four to five hours. Using computerized, single specimen, unloading compliance methods it is now possible to to obtain the J-R curve in a matter of twenty to thirty minutes after the test starts. The obvious savings in specimen preparation and data reduction have made the J-integral a valuable means of analysis where no practical means previously existed.

C. TEST CRITERIA

The test method developed in this thesis is specifically designed for use on a three point bend specimen. It utilizes the *single specimen* approach by relating the crack opening displacement (COD) compliance to the crack length.

The following equations are currently used by DTNSRDC. For bend specimens with a span to width (S/W) ratio of 4.0, Dr. J. Joyce [Ref. 17] of the United States Naval Academy determined:

$$a/W = 0.998265 - 3.81662 * U - 1.80596 * U^2 + 32.31038 * U^3 - 44.15665 * U^4 - 52.67876 * U^5$$

where

a = crack length

W = specimen width

$$U = \frac{1}{\left(\frac{4 * B_e * E * W * compl}{S}\right)^{1/2} + 1}$$

where

B_e = effective thickness = Bmax - (Bmax - Bmin)^2/Bmax

E = material's elastic modulus

S = span between supports

W = specimen width

compl = compliance = 1/slope of the load versus COD line for the specific unloading.

The reason for using the single specimen approach has already been presented. The reasons a bend type specimen and COD type unloading compliance are used are:

a. Three point bend specimen geometry is better suited than compact tension specimens for testing weldments.

b. Three point bend specimen geometry is also easier to machine than compact-tension specimens.

c. COD voltage readings are less susceptible to noise than linear variable differential transformer (LVDT) voltages used to measure load line displacement.

d. The COD compliance equation affords 0.1% fitting accuracy and allows comparison of results with DTNSRDC test data [Ref. 17].

III. TEST METHOD

A. OVERVIEW

A J-integral test can be divided into three distinct steps, 1) pre-test, 2) test, and 3) post-test. Each of these are described in greater detail in this chapter and presented as a step by step procedure in Appendix A.

After the specimen is machined it must be precracked using cyclic fatigue loading to minimize residual stresses and create a sharp crack tip [Ref. 5]. A computer program was developed to assist the operator in accomplishing this. The program computes the loading parameters for precracking in accordance with ASTM Standards E399-83 and ASTM E813-81 [Ref. 3 and 5]. The operator uses this information to run the MTS machine.

During the J-integral test a second computer program collects and records the load, COD, and load point displacement (deflection). These data are used by the program to determine J and the amount of crack extension for each operator controlled unloading cycle. An unload cycle consists of decreasing the load by 10% of the expected maximum load and reloading to the original load point. The program provides the operator with a real-time graphical representation of the any two parameters (load versus COD or deflection) during the test. It will also plot the J-R

curve and compute J_{Ic} upon completion of taking all the test data. Data are stored on diskette to serve as a record and allow future recall listing or plotting.

The post-test process includes heat tinting the specimen to aid in visual verification of crack extension upon completion of the test as required by ASTM Standard E813-81 [Ref. 5].

B. SPECIMEN PREPARATION

Figure 4 shows specifically the dimensions used in preparing eight specimens from two different one inch thick welded plates of HY-80. One plate was preheated while the other was not. It was necessary to reduce the width to approximately 0.95 inches to remove the distortion (bow) created by the weld. Four specimens were prepared from each plate, the machined notch was placed in the weld metal for two and in the base metal for the other two. The clip gage (used to measure COD) is attached to the top of the specimen by means of two cut razor blades. The blades are held down by small straps which allow adjustment of the initial gap. The initial gap is set to 0.475 inches, the calibrated zero setting for the clip gage, by means of a machined gage tool that rests in the specimen's machined notch. This method is also used by DTNSRDC.

Two additional holes are drilled and tapped for retaining a small bracket on the face of the specimen. The

bracket is used to provide a sensing point for a linear variable differential transformer (LVDT). The LVDT signal is used to calculate the area under the load versus displacement curve. At present the external LVDT is unable to control the MTS machine so the current method uses the MTS' internal LVDT to measure deflection via actuator movement.

Clarke [Ref. 16] states that side grooves improve the accuracy of calculating the crack length when using unloading compliance procedures. The side grooves reduce plastic deformation on the surface and aid in propagating a straighter crack front. DTNSRDC has found 20% side grooving produces the best results, hence the same was used for this work.

After the specimen is prepared a test record sheet (see Appendix B) is completed. Notch and side groove depths can be measured using a dial indicator with a needle tip. The record provides the operator with ready access to the information necessary to run the precracking and test programs.

C. PRECRACKING

Before the J-integral test can be performed the specimen must be precracked to establish a sharp crack tip. ASTM Standards E813-81 and E399-83 establish parameters that must be met during precracking to prevent over-stressing the

specimen or propagating the crack through the entire width. Precracking is accomplished with the aid of a program called "PRECRACK" which will compute loading requirements based upon these paramenters.

The program, written in HP-Basic, affords flexibilty by allowing the use of different bend specimen sizes and materials. It is easy to use due to its interactive design and easy to modify should such a need arise. A listing of "PRECRACK" is provided in Appendix D.

The operator is requested by the program to enter specific specimen data. The program will compute the initial maximum and minimum loads and change in the associated stress intensity factor (delta K). If this delta K exceeds 40 $ksi \cdot in^{1/2}$ then new maximum and minimum loads are computed. The operator is responsible for ensuring the MTS machine is operating within the prescribed limits. The operator can obtain a hard copy of the entered and computed data for record purposes (see Appendix G).

The MTS machine produces cyclic loading by means of an inverted (compressive load) haver sine wave.

The operator must periodically interrupt the cyclic loading and measure the current crack length by manually loading and unloading the specimen (determine the specimen's compliance). The program computes the new crack length and new loading limits. During the last 50% of precracking:

$$P_{max} < .4P_L$$

where

Pmax = maximum load

P_L = [(4/3) * (B * b^2 * Fs / (2 * Hs))]

where

B = net thickness (Bmin if specimen has side grooves)

b = current uncracked ligament (W-a)

Fs = flow stress ((Ys+Uts)/2)

Hs = half span

and Delta_K/E < 0.005 $mm^{1/2}$ (0.001 $in^{1/2}$) whichever, produces the least load [Ref. 5]. The program will automatically begin using these parameters when the most recently calculated crack length exceeds this 50% of the required extension to reach a/W = 0.6. This value is used because it is the optimum crack length with which to begin the J-integral test [Ref. 5].

D. J-INTEGRAL TEST

The J-integral test is performed by slowly applying a load to the specimen and periodically unloading it by 10% of the expected maximum load. The MTS machine is set up in stroke control with a very small inverted ramp function resulting in a loading rate of 0.005 inch/minute. The operator must again interrupt the MTS program and manually unload the specimen. Each unloading cycle (unload and reload) provides the necessary information to compute the current crack length. The crack length is then used to

determine the value of J up to that point. The computer program "J_INTGL" provides the operator with pertinent information during the test. Once the test is completed, the operator can obtain the J-R curve and value of J_{Ic} (see Figure 4 and Appendix H). The program will use only data points between the offsets, (blunting line + 0.15mm) to (blunting line + 1.5mm) as required ASTM Standard E813-81 when computing the linear regression line. A minimum of four data points must be within the offsets and one must lie near (within 1/3 the overall range of delta_a) the blunting line. Specific acceptability criteria for data is provided in ASTM Standard E813-81 [Ref. 5].

The program "J_INTGL" is the foundation of the test method, the single specimen approach would not be possible without it. The program collects, manipulates, displays and records all pertinent data during the test. A flow chart of "J_INTGL" is provided in appendix C. A listing of "J_INTGL" is provided in Appendix E.

Deflection measurements are presently taken using the LVDT installed in the MTS machine. A correction is therefore required to account for the system's compliance while loading a specimen. The correction was obtained by loading the system with a two inch thick piece of HY130 and recording the stroke reading for various loads. This process was checked three times with consistent (within 5%)

results. A plot of the data and the 4th order ploynomial curve fit is included as Figure 5.

E. POST TEST VERIFICATION

The results must be verified upon completion of the test. ASTM Standard E813-81 presents the following criteria that must be met before the test can be considered valid:

1. Total crack extension (visually measured) must be within 15% of that recorded during the test.
2. b_i and Bmin > 25 * J_{IC} / Fs (all terms are as defined earlier except b_i = post-fatigue uncracked ligament).
3. The slope of the linear regression fit to the data must be less than flow stress (dJ/da < Fs).

IV. RESULTS

A. TEST RESULTS

Specimen HY80-5B, prepared from the base metal of the preheated welded plate, was precracked,and tested resulting in a J_{Ic} value of 142 kJ/m^2. Figure 8 is a tracing of a photograph of the final fracture surface after heat tinting. All post test checks were completed and yielded satisfactory results. The J_{Ic} value is in good agreement with previous tests of HY80 plate as conducted by DTNSRDC resulting in an average J_{Ic} of 144 kJ/m^2 [Ref. 6].

Plots of J-R curve, load versus COD, load versus deflection and the are included as Figures 5, 6 and 7, respectively. The load versus deflection curve was obtained using the program "J_DATA", thus proving that the data is stored on disk, and is able to be recalled.

Data was taken at a nearly constant rate of 2.5 data points per second (150 per minute) while the program was executing.

Test reults were verified following the guidelines provided by ASTM Standard E813-81. The fracture surface was enlarged by taking a photograph, a tracing of which is included as Figure 8. The observed crack length was 14.4% longer than the last recorded crack length. This is within the acceptable limit (recall ASTM requires < 15%) but

because the clip gage reached its limit detector and caused the test MTS to stop between unloadings, it is possible some crack extension occurred after the last unloading cycle. This would help to explain the difference.

Additional information on this specific test is provided by being used in the example calculations shown in Appendix A. The exemplary computer output for each of the programs is also from specimen HY80-5B. (See Appendixes G, H and I).

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The method developed and presented by this work produces accurate and reliable results that meet the specifications established by ASTM Standard E813-81. Precracking specimen HY80-5B took approximately 2 hours and the J-test required approximately 2.5 hours including several pauses to manually verify several calculations. The time required for the processes will most likely decrease as operator experience and confidence increases.

All three computer programs have run successfully and perform as intended.

B. RECOMMENDATIONS

As with all first versions of computer programs as extensive as "J_INTGL", changes and improvements are to be expected. The following programming changes may be of value to future operators:

1. Display pertinent information (i.e. current crack length in both English and metric units (currently only metric is provided).
2. Provide a means of storing the data arrays during the test without being required to rerun the entire

program (re-entering specimen data, conversion data, etc.)

3. Provide a means of eliminating a specific J-R data point from being used in obtaining the linear regression fit. This may be programmed to be accomplished automatically by applying Chauvenet's Criterion to the data.

Improvements in the current means of conducting the test can also be made, such as making the MTS control both loading and unloading using the same rate, requiring the operator to do no more than press a button or throw a switch. Lastly, pursue the use of the external LVDT, this will eliminate the need for correcting the deflection reading and speed up the rate of data acquisition.

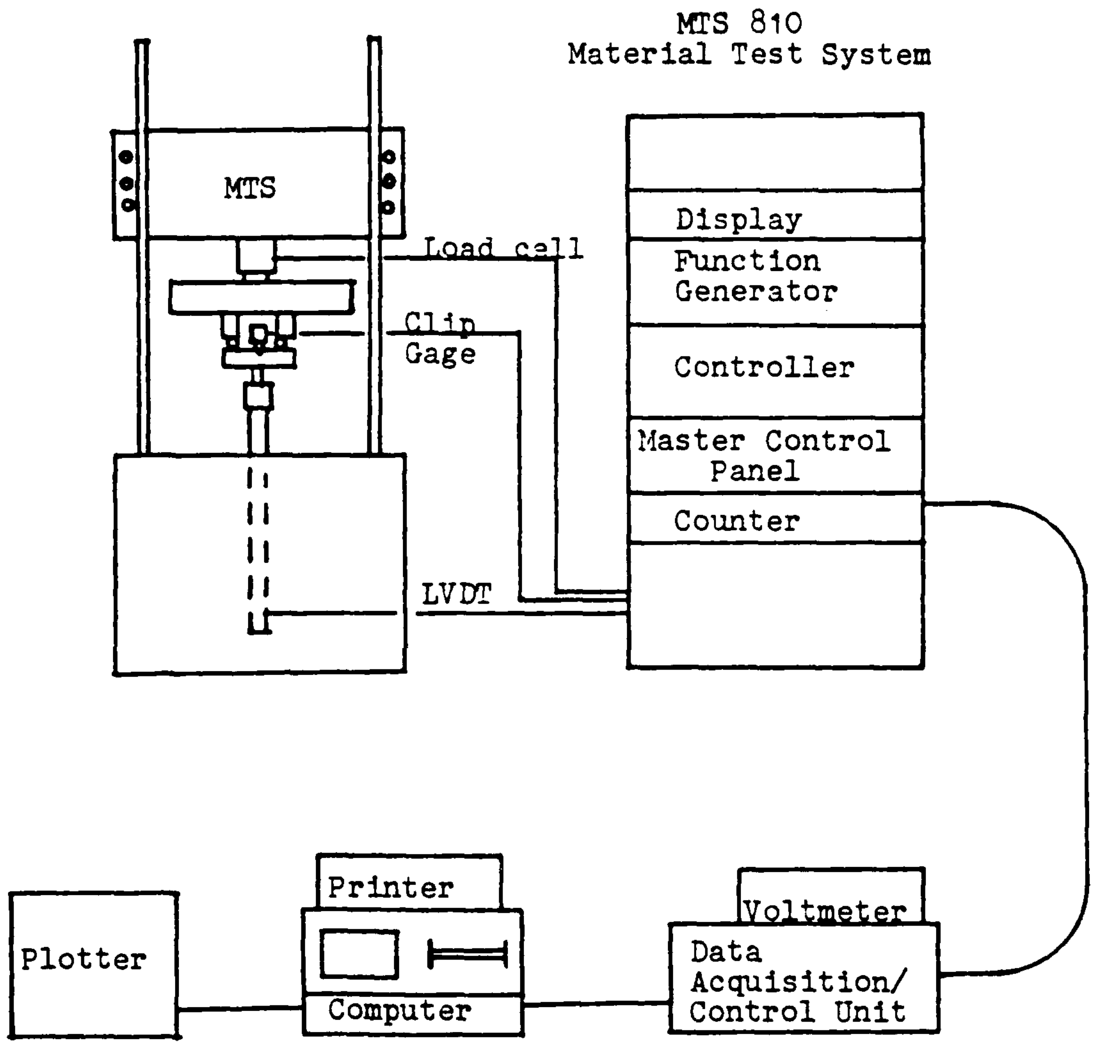


Figure 1. System Layout

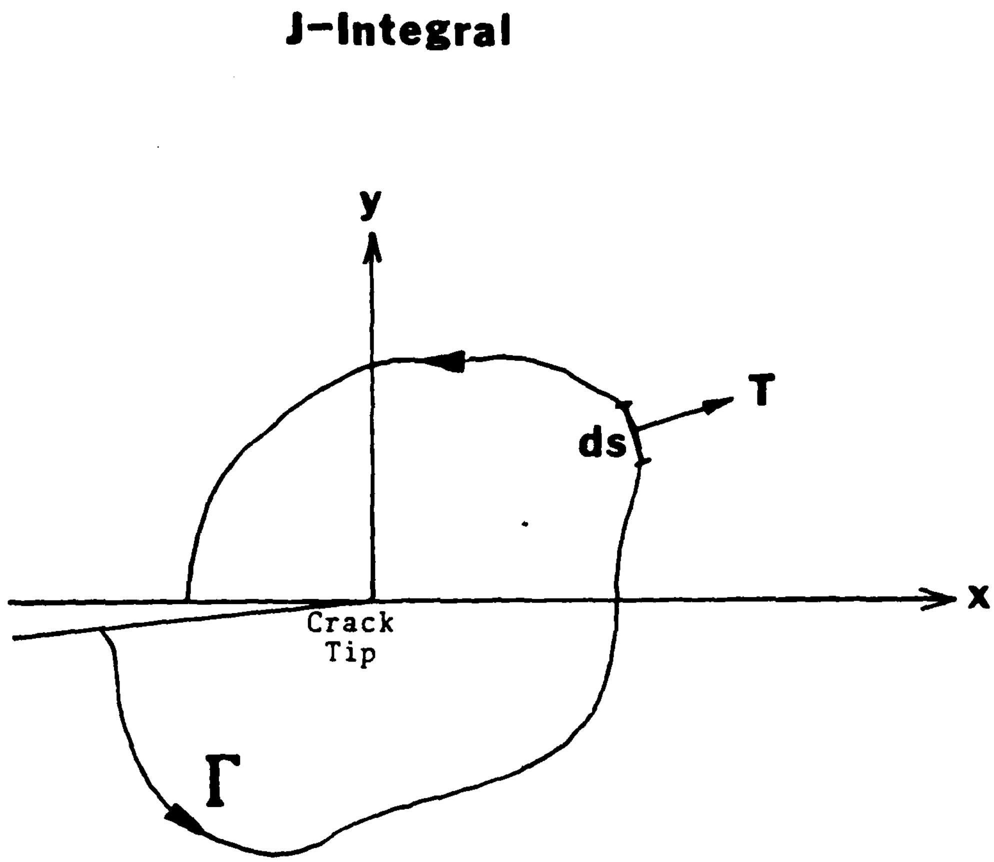


Figure 2. Pictorial Representation of J-Integral

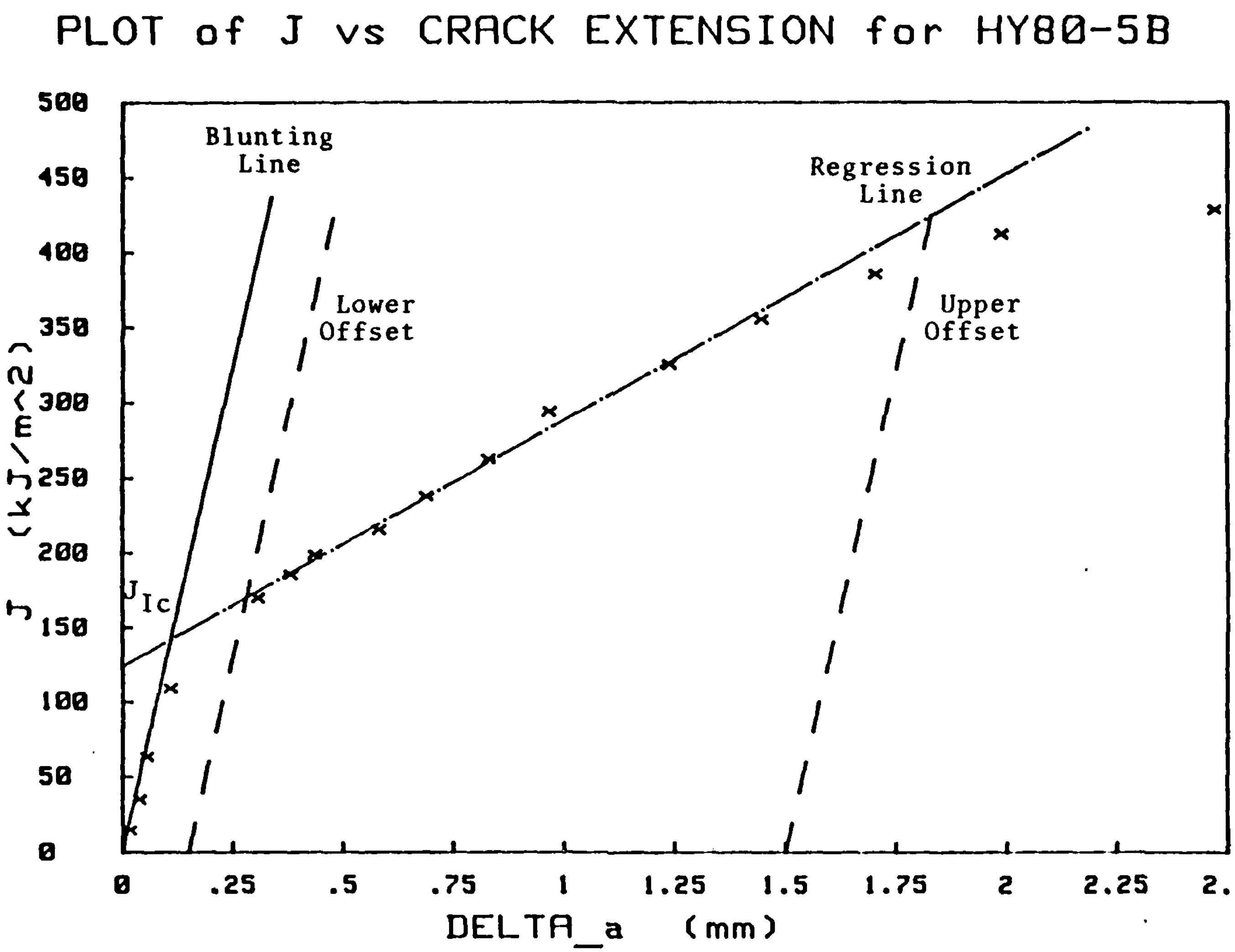


Figure 3. J Versus Crack Extension for HY80-5B

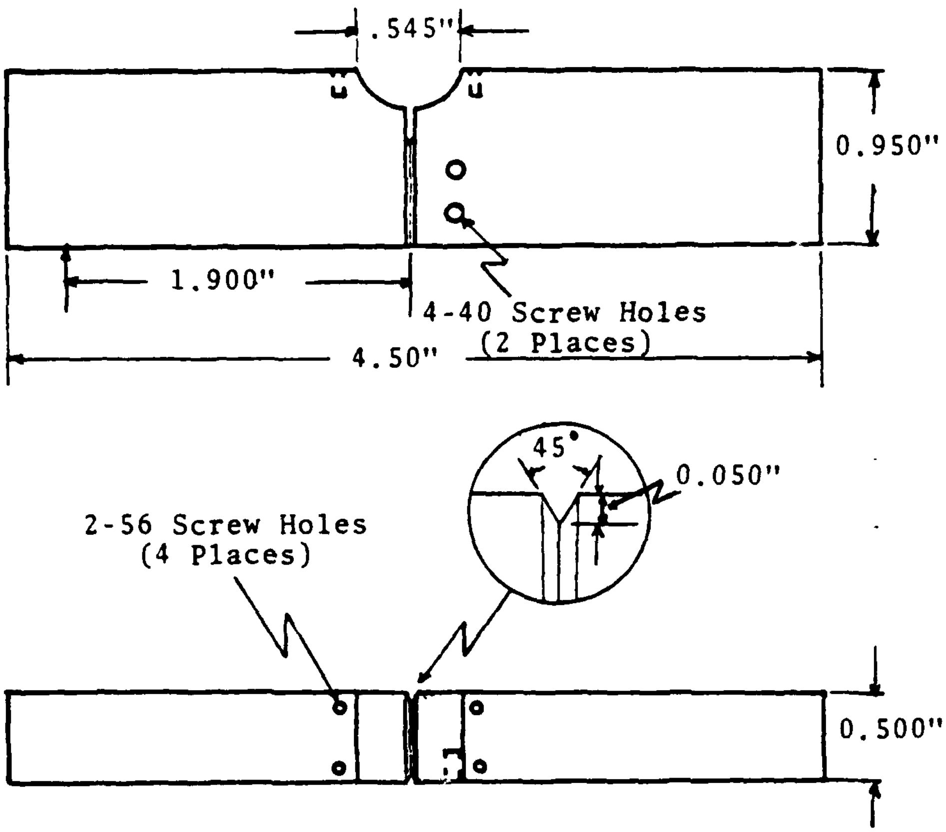


Figure 4. Specimen Drawing

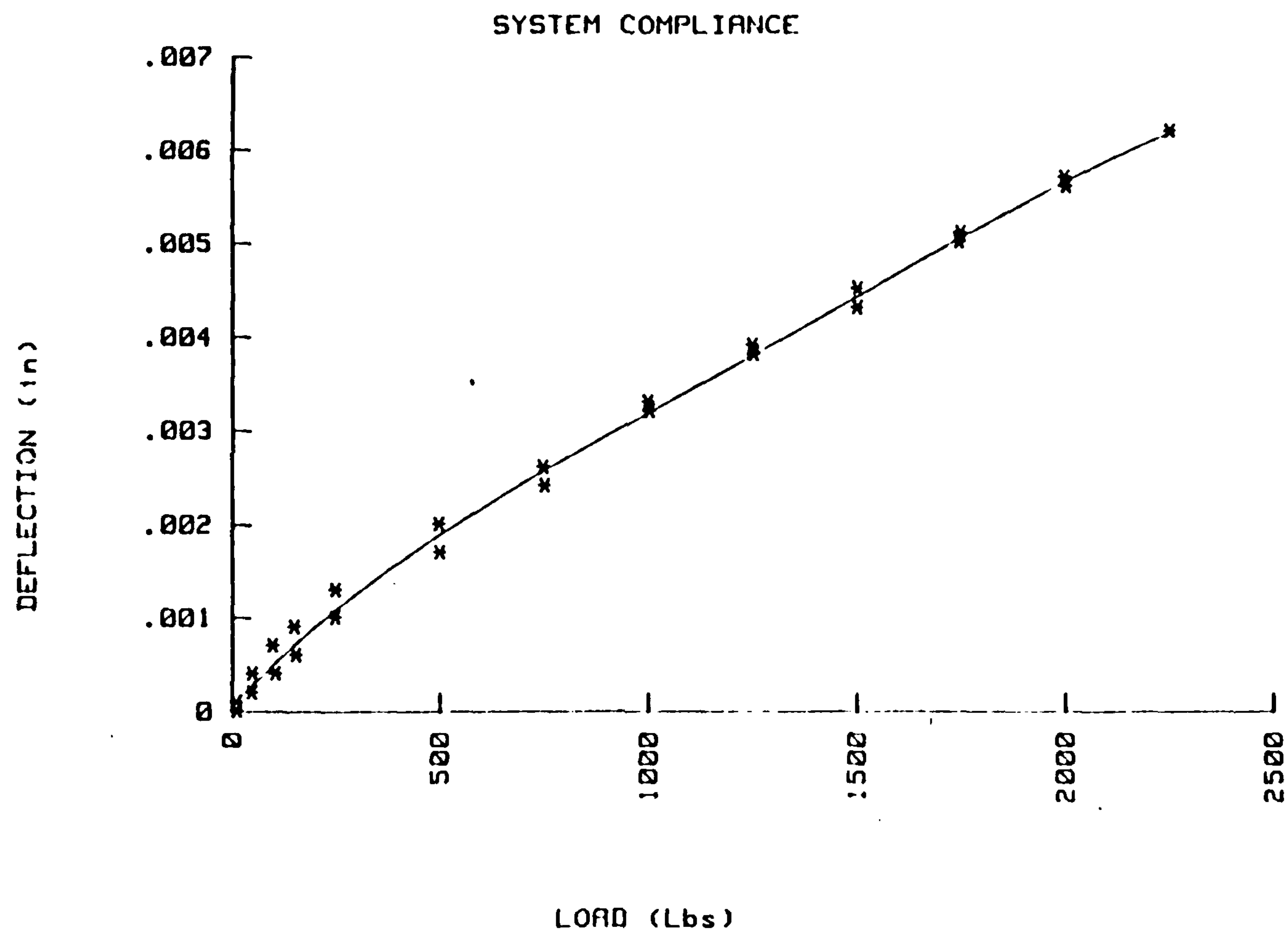


Figure 5. Plot of System's Compliance

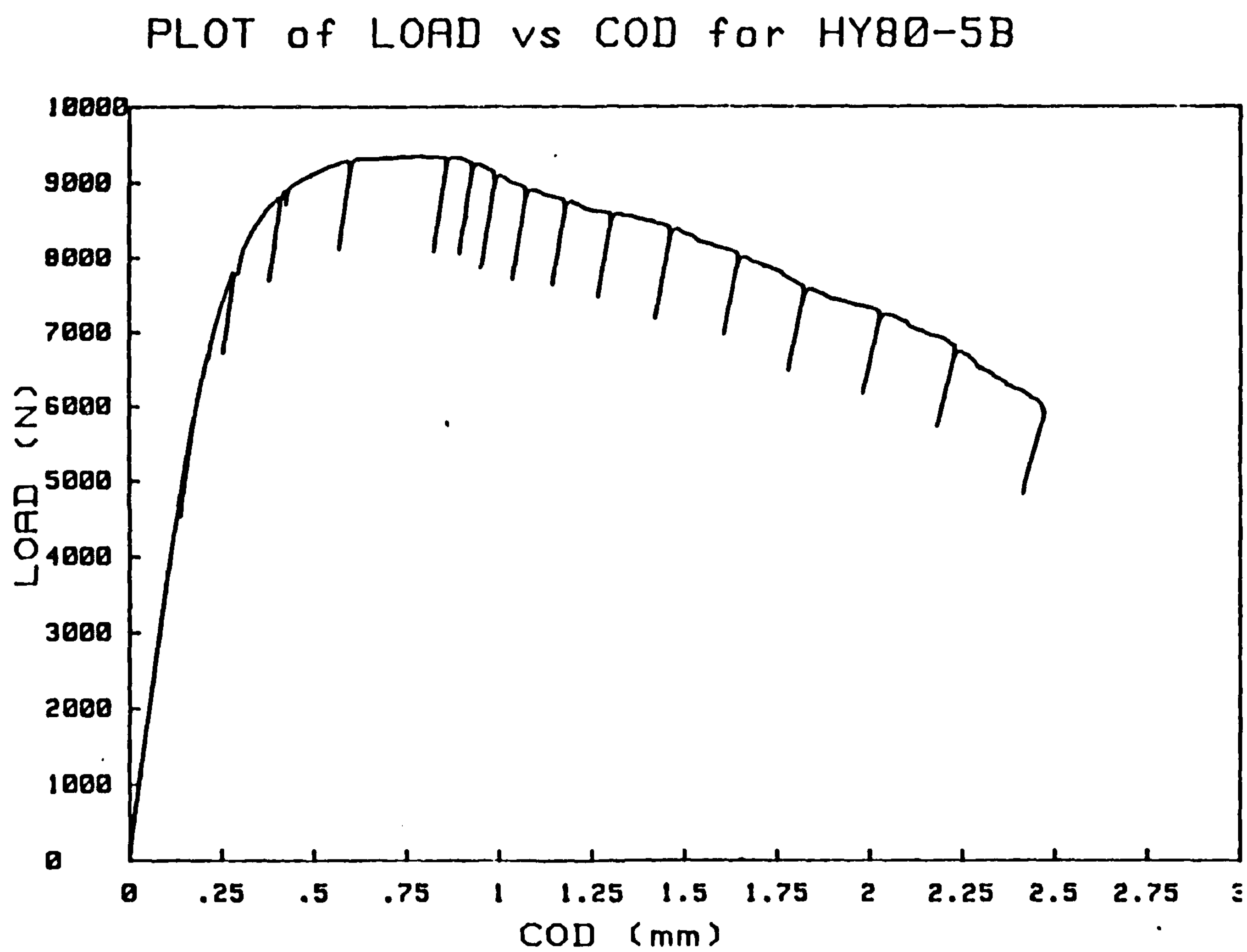


Figure 6. Plot of Load Versus COD for HY80-5B

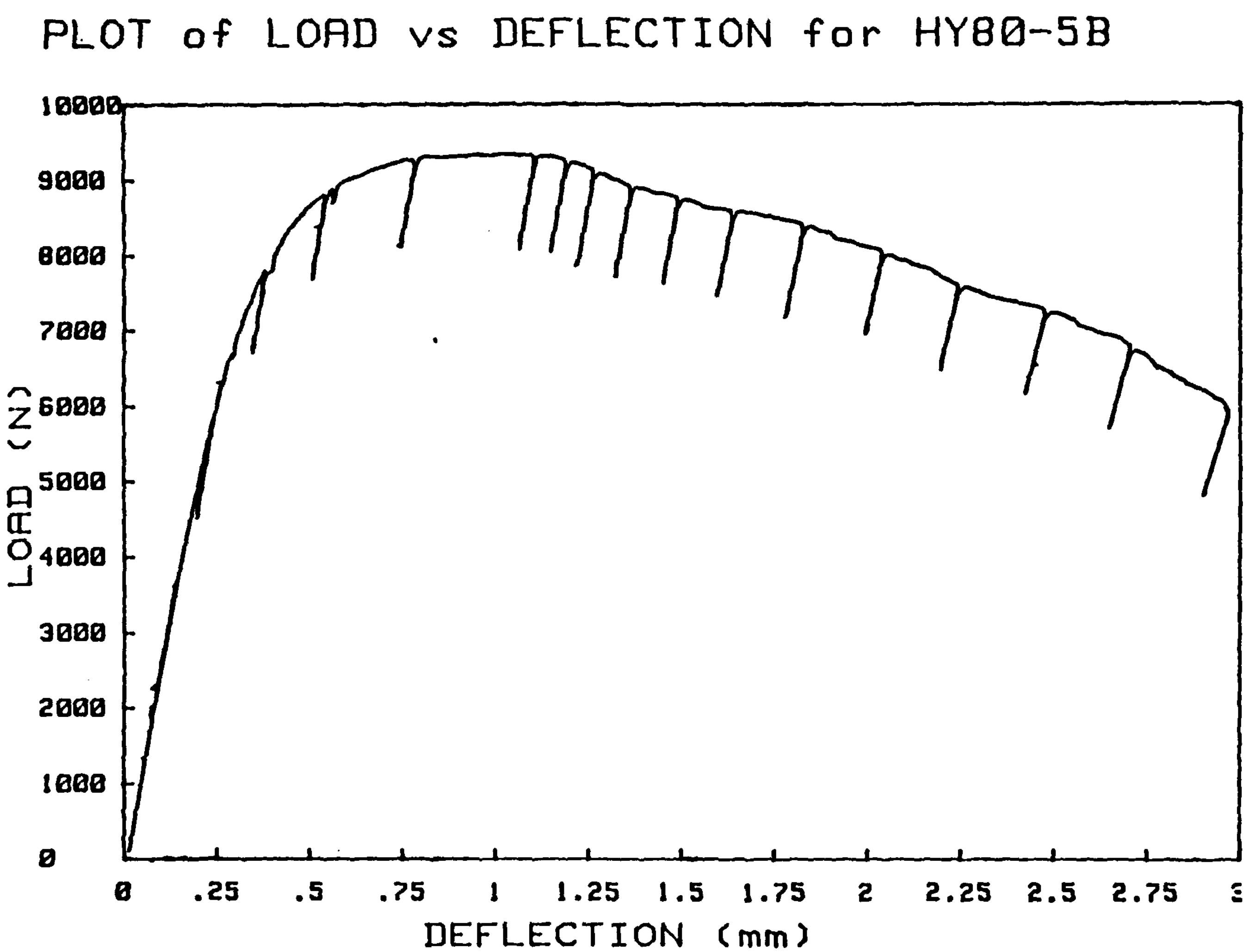


Figure 7. Plot of Load Versus Deflection for HY80-5B

Fracture Surface

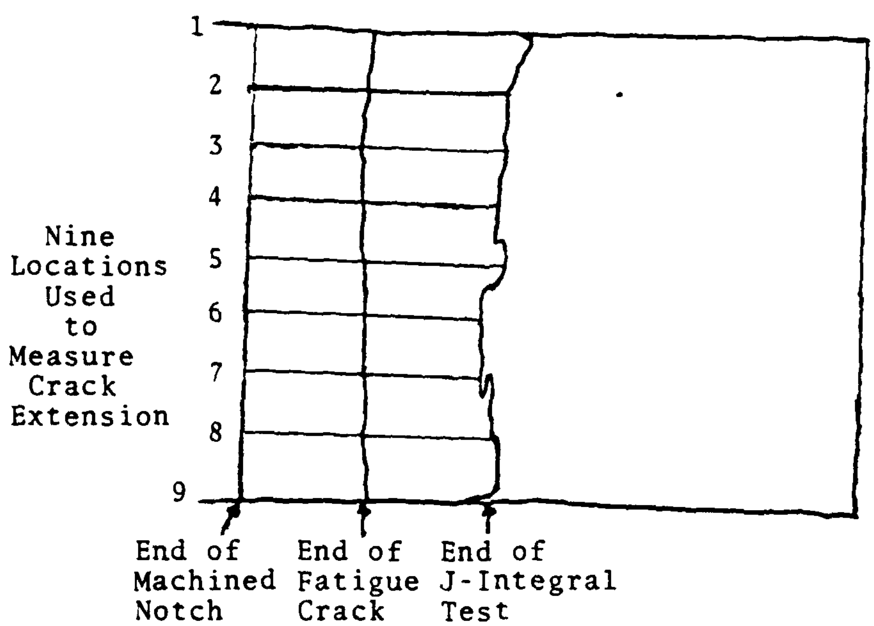


Figure 8. Tracing of HY80-5B Fracture Surface

APPENDIX A

TESTING METHODS

A. INTRODUCTION

The steps required to perform a J-integral test using a single specimen approach can be divided into three major categories, pre-test, test, and post test. Each of these categories may be further divided as shown below.

1. Pre-test
    a. Machine specimen
    b. Precrack specimen by fatigue loading
2. Test
    a. Run J-integral test
3. Post-test
    a. Heat tint specimen and break apart
    b. Measure crack extension and verify results

Each process is described in greater detail in this appendix. A working knowledge of the equipment is presupposed and awareness of all safety precautions is required before operating the MTS.

B. PRE-TEST

a. Machine Specimen

ASTM Standard E813-81 provides very specific guidance on specimen dimensions. All dimensions are related to the

width (W). Fatigue precracking is enhanced if the radius at the tip of the notch is kept to approximately 0.003 inches. This was accomplished by machining with a special cutter which was used to make only the final passes in the notch. Figure 2 can be consulted for the actual dimensions used to machine the specimens used in this work.

b. Precracking

The following step by step guide is provided to assist operators.

1. Before turning on the MTS machine ensure the proper range card is installed in the strain signal conditioner for the clip gage to be used.

2. Turn on power to all equipment with the computer being switched on last.

3. Load and run "PRECRACK" program on the HP-9826 computer.

4. Select range scales on MTS;

example: 10 v = 4000 lbs 20% of full load (range #3)

10 v = 0.02 in 10% of full clip gage (range #4)

10 v = 2.5 in 50% of full stroke (range #2)

5. Press k0-key on computer and enter specimen data as requested.

6. Press k2-key and enter conversion data as requested.

7. Press k5-key to obtain a table of COD readings for various loads and crack lengths.

8. Set READOUT knobs on the MTS Controller to be:

top = load

middle = strain

bottom = stroke

Set all to (+) polarity. See Figure A1. This ensures channels of the MTS machine are properly aligned with the data acquisition system.

9. Set MTS limit detector switches based on the information just generated by the program. Limit switch settings are determined by the simple formula:

Limit switch = L * 10 / FSR

where

L = desired limit in English units

FSR = full scale range of current operating being used in English units

example "PRECRACK" determined:

Pmax = 1668 lbs set load limit to 1600 lbs for specimen HY80-5B

load limits:

upper limit --- small positive load for example 40 lbs (should never be positive)

+40 lbs * 10 v / 4000 lbs = +0.1 v

therefore set upper limit knob to +0.1 v

lower limit --- 1600 lbs maximum load

-1600 lbs * 10 v / 4000 lbs = -4.0 v

therefore set lower limit knob to -4.0 v

strain limits:

upper limit --- 0.01 in beyond maximum expected during precracking

+0.01 in * 10 v / 0.02 in = +5.0 v

lower limit --- some small value for example -0.1 v (should never be negative)

stroke limits:

upper limit --- 1.5 in to allow clearance for installing specimen and yet stop the MTS if this limit is reached

+1.5 in * 10 v / 2.5 in = +6.0 v

lower limit --- 0.25 in of compressive actuator movement is more than sufficient for precracking

-0.25 in * 10 v / 2.5 in = -1.0 v

10. Adjust the upper roller supports as required to obtain a span-to-width ratio (S/W) of 4.0.

11. Install specimen (with the clip gage already installed) using alignment collars to properly center.

12. Zero the load and strain voltages.

13. Reset and clear all limit switches (all green lights on controller panel should be showing).

14. Using load control energize hydraulics and apply a low (<100 lbs) compressive load to the specimen by <u>SLOWLY</u> turning the SETPOINT knob counter-clockwise.

15. Slowly decrase the compressive load on the specimen to between 5 and 10 lbs by turning the SETPOINT knob clockwise and then zero the stroke voltage reading.

YOU ARE NOW READY TO OBTAIN AN UNLOADING COD COMPLIANCE MEASUREMENT OF THE CRACK LENGTH

16. Press k4-key on the computer and proceed with taking data.

17. Slowly, and as smoothly as possible increase the load to approximately 500 lbs and return to approximately 20 lbs ending the loading cycle with a slight (10 lbs) increase to trip the computer out of the data-taking loop.

The computer will display all pertinent crack length information and ask if you want another measurement. You may repeat this process as often as you like, just be sure the maximun load is lower than that required to extend the crack.

18. Make necessary adjustments to the MTS such that the strain limit switch will trip the MTS when the crack extends to 50% of the desired extension. This is determined by interpolating results from the table obtained earlier. (See Step 7).

NOTE: As the crack propagates the acceptable maximum load decreases. For the specimen, [illegible]90-5B, used to test this program a Pmax = 1000 lbs was suitable to initiate the crack and propagate it to 50% of the desired extension (a = 0.506 in).

Example:

50% crack extension = crack length (a) of 0.506 in

from table:

COD = 1.7 volts at 1000 lbs and a = 0.506 in

Therefore set UPPER STRAIN LIMIT SWITCH to +1.7 v.

YOU ARE NOW READY TO BEGIN CYCLIC LOADING

19. Setup MTS:

DISPLAY:

a. Setup to read maximum and minimum load in lbs.

FUNCTION GENERATOR:

a. CONTROL MODE: Remote
b. RATE 1: 10 Hz
c. RATE 2: N/A
d. HOLD BUTTON: In
e. BREAKPOINT: N/A
f. HAVER SINE: In
g. INVERT: In

CONTROLLER :

a. SPAN 1: 0.0
b. SPAN 2: 0.0

COUNTER:

a. COUNTER INPUT: Oscillator
b. COUNTER MULTIPLIER: X100
c. Press RESET

20. Slowly increase the SETPOINT to Pmin.

21. Press the RUN button on the CONTROLLER and then release the HOLD button of the FUNCTION GENERATOR.

22. Slowly increase the span of the cyclic loading using SPAN 1 knob to the desired Pmax.

The MTS will continue cyclic loading until it is manually stopped or a limit detector is tripped. Most likely the COD limit detector will trip at which time the machine will will stop and unload the specimen.

23. A new crack length measurement can now be obtained using the same manual process as described in Step 16 and Step 17.

24. Readjust limit switches and resume fatigue loading as done in Steps 18 through 22.

25. Continue this process until the crack reaches the desired length.

C. J-INTEGRAL TEST

The following steps are required to run a J-integral test. They are very similar to those used in precracking. The major change is that a ramp function under stroke control is now used to control the MTS machine.

1. Before turning on the MTS machine ensure the proper range card is installed in the strain signal conditioner for the clip gage to be used.

2. Turn on power to all equipment with the computer being switched on last.

3. Load and run "J_INTGL" program on the HP-9826 computer.

4. Select range scales on MTS;

example: 10 v = 4000 lbs 20% of full load (range #3)

10 v = 0.02 in 10% of full clipgage (range #4)

10 v = 0.5 in 10% of full stroke (range #2)

5. Press k0-key on computer and enter specimen data as requested.

6. Press k1-key and enter conversion data as requested.

7. Press k3-key and follow instructions for creating a data file on an initialized data diskette. See HP-Mannual on how to initialize a diskette if necessary.

8. Press k3-key to setup the plotter.

9. Press k5-key and obtain the maximum load you may apply while measuring a0.

YOU ARE NOW READY TO SETUP THE MTS MACHINE

10. Set READOUT knobs on the MTS Controller to be:

top = load

middle = strain

bottom = stroke

Set all to (+) polarity. See Figure A1.

11. Set MTS limit detectors switches.

example:

Pmax = 895 lbs for HY80-5B (see Appendix H)

load limits:

upper limit --- small positive load (40 lbs)

(should never be positive)

+40 lbs * 10 v / 4000 lbs = +0.1 v

lower limit --- 895 lbs compression maximum

-895 lbs * 10 v / 4000 lbs = -2.125 v

strain limits:

upper limit --- want to be able to read full scale on range #2 (0.1 in)

+0.1in * 10 v / 0.1 in = +10 v

lower limit --- a very small value set to -0.1 v

(should never be negative)

stroke limits:

upper limit --- full scale (+10.0 v) on this most sensitive scale

lower limit --- a maximum compression of 0.25 in is sufficient for the test and will stop the actuator before it can cause any serious damage to the specimen holder

-0.25 in * 10 v / 0.5 in = -5.0 v

12. Adjust the upper roller supports as required to obtain a span-to-width ratio of 4.0.

13. Install the specimen (with the clip gage already installed) using the alignment collars to properly center.

14. Zero the load and strain voltages.

15. Reset and clear all limit switched (all green lights on controller panel should be showing).

16. Using load control energize hydraulics and apply a low (<100 lbs) compressive load to the specimen by SLOWLY turning the SETPOINT knob counter-clockwise.

17. Decrease the load to between 5 and 10 lbs and zero the stroke voltage.

18. Adjust the MTS to the following settings:

DISPLAY:

a. Setup to read load in lbs and stroke in inches.

FUNCTION GENERATOR:

a. CONTROL MODE: Remote
b. RATE 1: 6000 (sec)
   as determined by: desire 0.005 in/min loading rate therefore;

0.5 in (full scale) / 0.005 in/min * 60 sec/min = 6000 sec

c. RATE 2: N/A
d. HOLD BUTTON: In
e. BREAKPOINT: N/A
f. RAMP BUTTON: In
g. INVERT: IN

CONTROLLER:

a. SPAN 1: 10.0 (full scale)
b. SPAN 2: 0.0

COUNTER: N/A

YOU ARE NOW READY TO MEASURE THE INITIAL CRACK LENGTH

19. The computer will begin taking data after the 'CONTINUE' key is pressed. The MTS will begin loading the specimen after the MTS' RUN switch is pressed and the HOLD button is released.

20. When the desired maximum load (approximately 500 lbs) is reached; depress the HOLD button, switch to load control, and manually decrease the load (to approximately 20 lbs) by <u>SLOWLY</u> turning the SETPOINT knob clockwise. As with precracking you must end the unloading with a small increase in load (10 lbs from where you stop) to signal the computer you have completed the load/unload cycle. The computer will

plot the data as you go, ensure you remain on the linear portion of the loading curve.

21. The computer will display all the pertinent crack length information. You may repeat this operation by switching back to stroke control and repeating Steps 19 and 20 as often as you like as long as you remain on the linear portion of the loading curve.

22. After the computer has stored the desired initial crack length (a0) measurement on data diskette, you are ready to begin propagating the crack.

23. Ensure you are in stroke control with near zero (<10 lbs) load and the RUN light is on with the HOLD button depressed.

24. Press the k7-key on the computer follow instructions and proceed to collecting data (data acquisition system will be continuosly switching channels and the plotter will be plotting), now release the HOLD button on the MTS.

25. When you reach a point where you wish to unload the specimen; press the HOLD button, switch to load control, and slowly decrease the load. The computer will beep when you have unloaded the specimen by 10% of the expected maximum load. Switch back to stroke control and release the HOLD button to reload the specimen.

26. When the load returns to the point from which the unloading began the computer will display and printout all

the information it has determined with regards to the current unloading cycle.

27. This process of switching control modes (Steps 25 and Step 26) are repeated for every unloading cycle until the you decide to stop by pressing the k9-key on the computer or one of the limit detectors shuts off the MTS machine. Remember, you must have atleast four data points between the offsets one of which lies near the blunting line on the J-R curve.

28. The k9-key interrupts the computer program and tells it to stop taking data and write the data it has collected on the data diskette.

29. The computer will then display a table of the collected J versus delta_a and ask if you desire a plot. Simply follow the directions from the computer and you will obtain the J-R curve and the value of J_{Ic}.

D. POST-TEST

The post-test includes verifying the final crack length, and validating the other parameters as discussed in ASTM Standard E813-81 such as:

$$b_i \text{ and } Bmin > 25 * J_{Ic} / Fs$$

where

b_i = uncracked ligament after precracking

Bmin = minimum specimen thickness

Fs = flow stress

and that the slope of the linear regression fit to the data is less than the flow stress (dJ/da < Fs). This data is obtained directly from the "J_INTGL" program output.

Heat tinting the specimen, 10 minutes at 300C for most steels, aids in the visual identification of the amount of crack extension. After the specimen is removed from the oven and air cooled, place it in liquid nitrogen to assist in obtaining a brittle fracture. After breaking the specimen apart, place the pieces in alcohol while returning to room temperature. This will prevent water vapor from condensing and freezing on the surface and minimize oxidation.

A photographic enlargement of the surface can now be obtained and the crack length can easily be verified. The final crack extension must be within 15% of that recorded during the test.

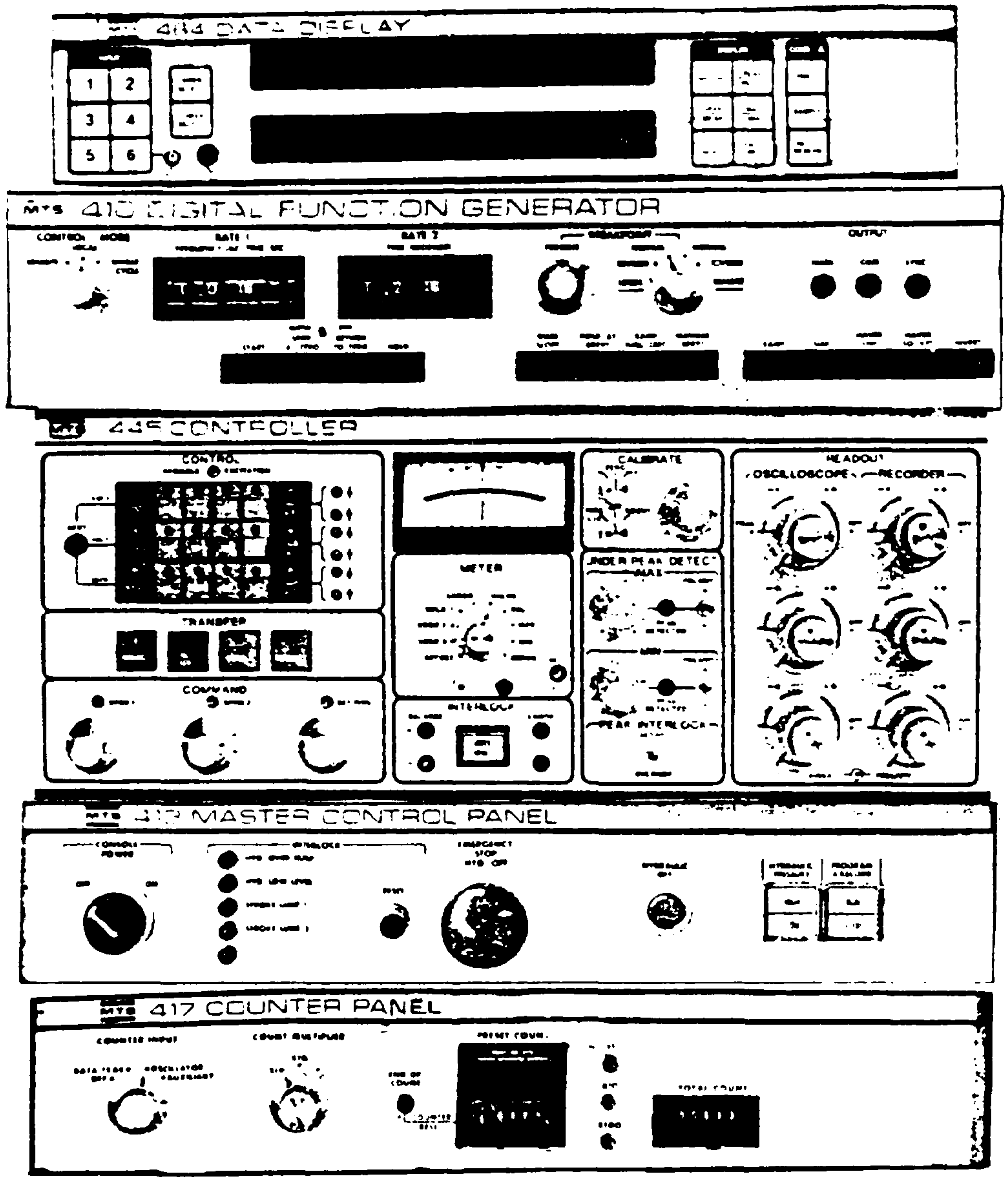


Figure A1. MTS Control Panel

APPENDIX B

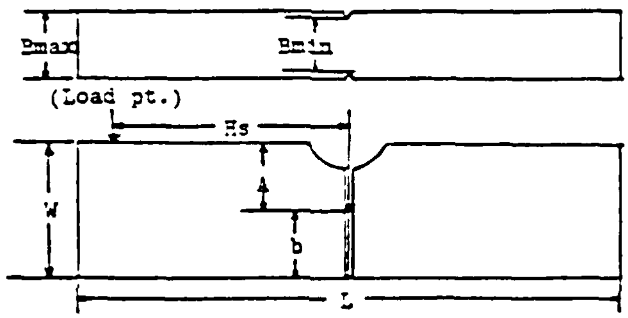
TEST RECORD SHEET

THREE POINT BEND SPECIMEN

TEST REPORT

SPECIMEN I.D.__________ MATERIAL__________ ORIENTATION_____

Date__________ Operator__________ Test Temp_______



W = ________ A = ________ b = ________ L = ________

Hs = ________ Bmax = ________ Bmin = ________

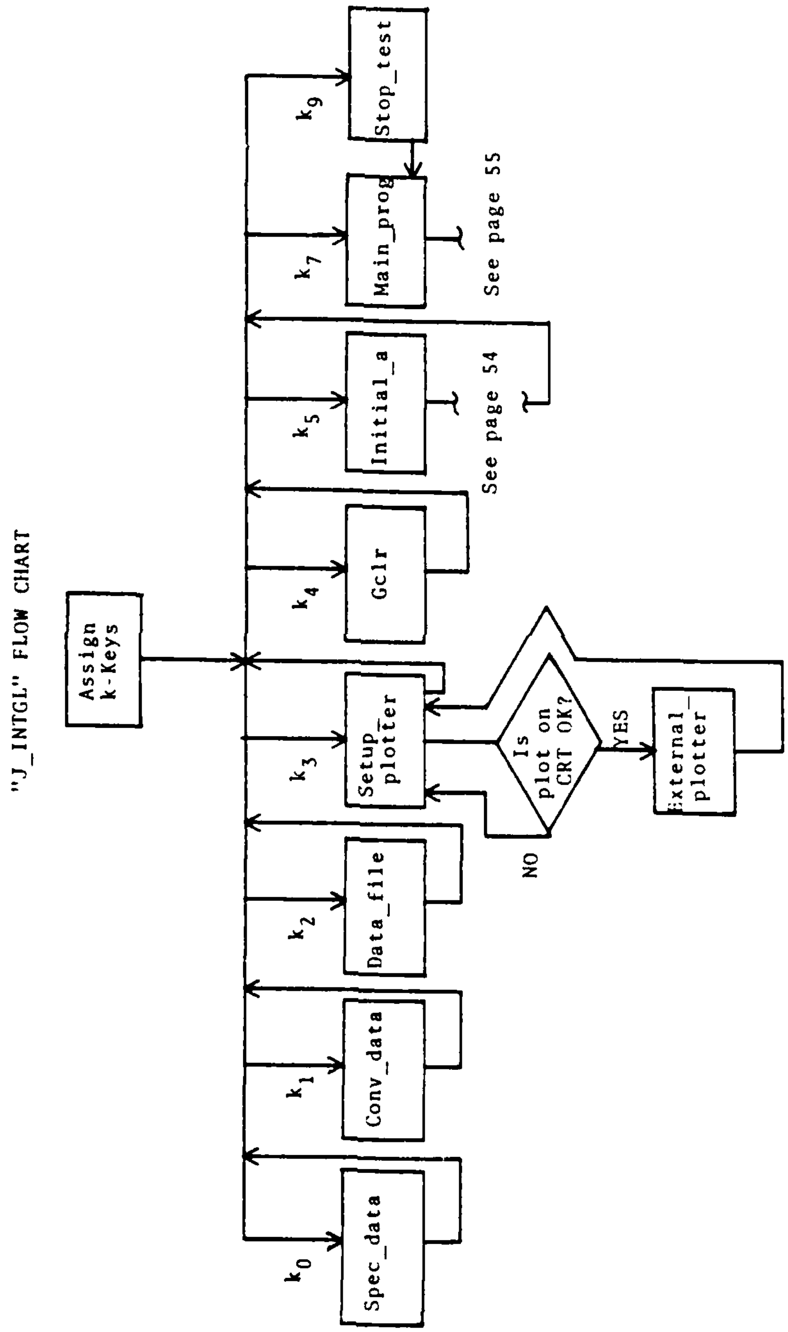
Ys = ________ Uts = ________ Fs = ________

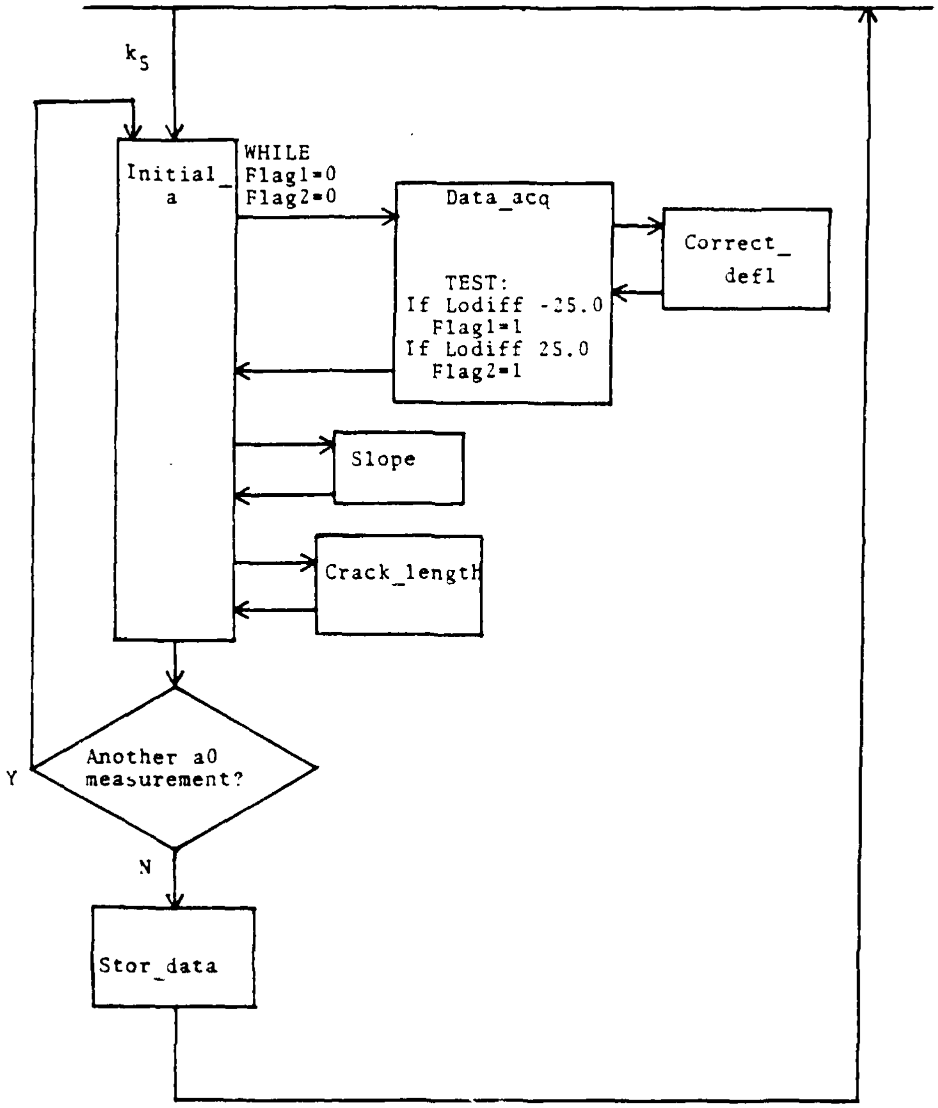
Poisson's ratio = ________ Elastic Modulus = ________

Comments:

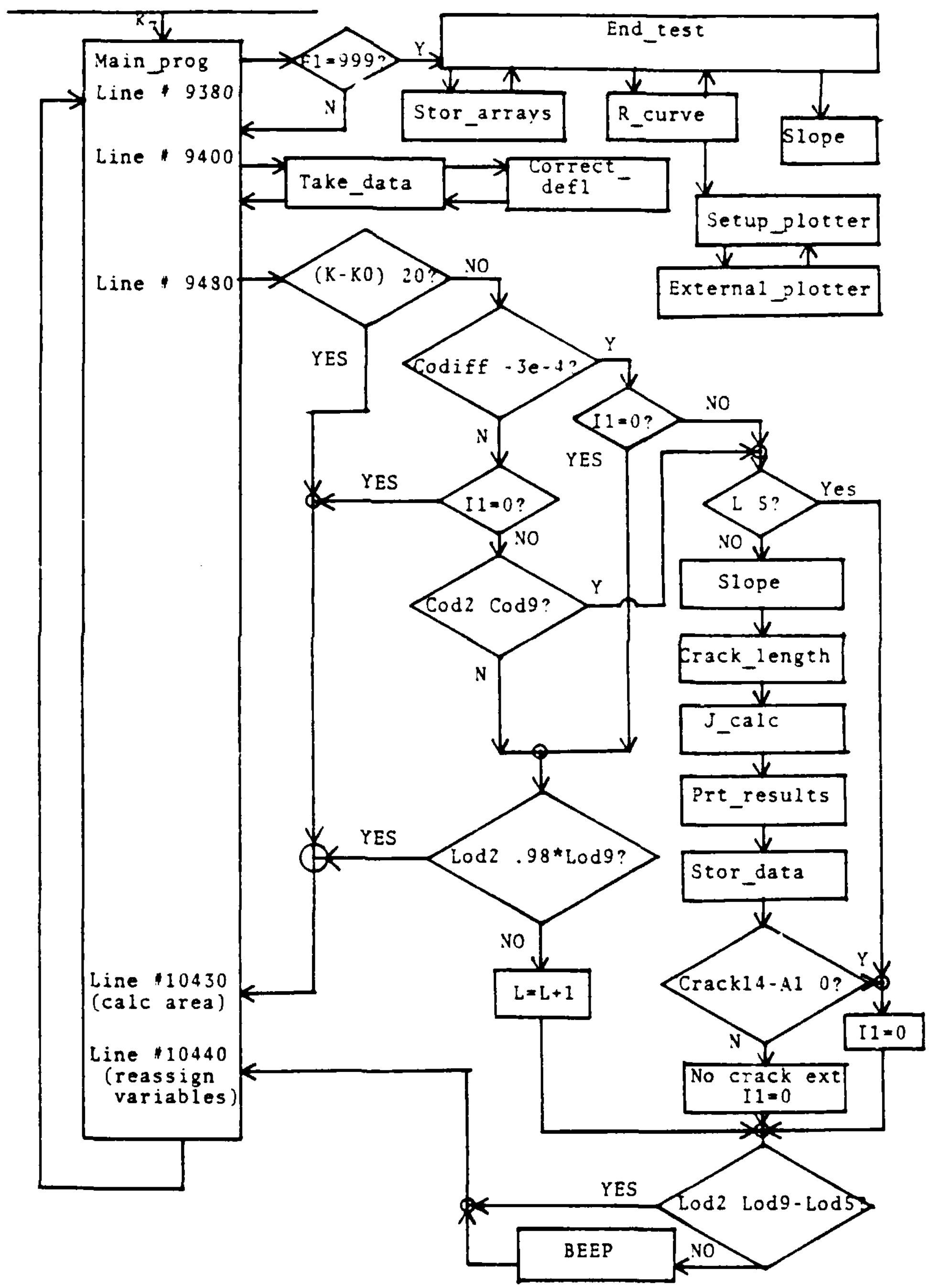
APPENDIX C

J_INTGL FLOW CHART





k_S
Initial_a
WHILE
Flag1=0
Flag2=0
Data_acq
TEST:
If Lodiff -25.0
Flag1=1
If Lodiff 25.0
Flag2=1
Correct_defl
Slope
Crack_length
Another a0 measurement?
Y
N
Stor_data


K
Main_prog
Line # 9380
Line # 9400
Line # 9480
Line #10430
(calc area)
Line #10440
(reassign
variables)
F1=999?
Y
N
End_test
Stor_arrays
R_curve
Slope
Take_data
Correct_
defl
Setup_plotter
External_plotter
(K-K0) 20?
NO
YES
Codiff -3e-4?
Y
N
I1=0?
NO
YES
I1=0?
YES
NO
Cod2 Cod9?
Y
N
L 5?
Yes
NO
Slope
Crack_length
J_calc
Prt_results
Stor_data
Lod2 .98*Lod9?
YES
NO
L=L+1
Crack14-A1 0?
Y
N
I1=0
No crack ext
I1=0
Lod2 Lod9-Lod5?
YES
NO
BEEP

APPENDIX D

PRECRACK LISTING

```
10    ! PRECRACKING PROGRAM FOR THREE POINT
20    ! BEND SPECIMEN. THIS PROGRAM INCORPORATES
30    ! THE USE OF THE FOLLOWING EQUIPMENT:
40    !      1. HP-9826 COMPUTER
50    !      2. HP-3497A DATA ACQUISITION SYSTEM
60    !      3. HP-2671G THERMAL PRINTER
70    !      4. MTS MACHINE
80    !
90    ! THE PROGRAM USES BOTH ENGLISH AND METRIC
100   ! UNITS. ALL METRIC VARIABLES ARE DENOTED
110   ! WITH AN m IN THEIR NAME ie Wm-WIDTH IN
120   ! METRIC UNITS (mm IN THIS CASE).
130   !
140   ! THIS PROGRAM WAS WRITTEN BY:
150   !      LCDR W. K. TRITCHLER, USN
160   ! VERSION 1.0      DATE 11/83
170   !
180   !
190   !
200   COM /J_intgl/ F1
210   !
220   ! DIM Lodm(2000),Deflm(2000),Codm(2000) these arrays will be dimensioned
230   ! required in the New_a routine.
240   ! Lodm(I) - LOAD IN NEWTONS
250   ! Deflm(I) - DEFLECTION IN mm
260   ! Codm(I) - CRACK OPENING DISPLACEMENT IN mm
270   !
280   DIM Coef(6),G(6),A0(100)
290   DUMP DEVICE IS 706
300   Dvm=709
310   CLEAR Dvm
320   PRINT CHR$(12)        ! CLEARS CRT
330   PRINT ""
340   PRINT "                PRECRACKING  PROGRAM"
350   PRINT "                    VERSION 1.0"
360   PRINT ""
370   PRINT "            WRITTEN BY LCDR W.K. TRITCHLER"
380   PRINT ""
390   PRINT "                PLEASE SELECT A k-KEY"
400   !
410   !****************************************
420 Begin: !
430   ON KEY 0 LABEL "SPEC_DATA" GOSUB Spec_data
440   ON KEY 2 LABEL "CONV_DATA" GOSUB Conv_data
450   ON KEY 4 LABEL "NEW_A" GOSUB New_a
460   ON KEY 5 LABEL "a_TABLE" GOSUB A_table
470   !
480   !****************************************
490   !
500 Spin:      ! WAITS FOR KEY INPUT
510   GOTO Spin
520   !
530   !****************************************
540   !
550 Spec_data:    ! INPUTS REQUIRED SPECIMEN DATA
560   PRINT CHR$(12)        ! CLEARS CRT
570   PRINT "INPUT SPECIMEN IDENTIFICATION (ID):"
580   INPUT D$
590   PRINT ""
```

```
600    PRINT "J-INTEGRAL TEST for ";D$
610    PRINT ""
620    PRINT "INPUT SPECIMEN DATA USING ENGLISH UNITS (LBS.      INCHES. etc.)"
630    PRINT ""
640    PRINT "WHAT IS THE SPECIMEN'S WIDTH. NOTCH LENGTH, Bmax.  Bmin (THICKNESS)
?"
650      INPUT W,A,Bmax,Bmin
660     PRINT ""
670    PRINT "WHAT IS THE SPECIMEN'S HALF SPAN AND POISSON'S     RATIO?"
680      INPUT Hs,Nu
690    PRINT ""
700    PRINT "WHAT IS THE SPECIMEN'S ELASTIC MODULUS, YIELD      STRENGTH AND ULT
IMATE STRENGTH?"
710      INPUT E,Ys,Uts
720    PRINT CHR$(12)              ! CLEARS CRT
730    Fs=(Ys+Uts)/2
740    PRINT "USING ENGLISH UNITS (in,lbs,psi)"
750    PRINT "THE FOLLOWING HAS BEEN ENTERED for: ";D$
760    PRINT "WIDTH =";W;"     NOTCH LENGTH =";A
770    PRINT "Bmax =";Bmax;"          Bmin =";Bmin
780    PRINT "HALF SPAN =";Hs;"   POISSON'S RATIO =";Nu
790    PRINT "YIELD STRENGTH =";Ys;"  ULTIMATE TS =";Uts
800    PRINT "ELASTIC MODULUS =";E;"   FLOW STRESS =";Fs
810    PRINT ""
820    PRINT "THIS PROGRAM ALLOWS NO EASY RECOVERY, IF ANY DATA IS INCORRECT YOU
MUST RE-ENTER ";
830    PRINT "EVERYTHING."
840    PRINT ""
850    PRINT "IS ALL DATA CORRECT?"
860    INPUT H$
870    IF H$="NO" OR H$="N" THEN 550    ! REPEATS Spec_data
880    PRINT ""
890    PRINT "DO YOU WANT A HARD COPY?"
900    INPUT H$
910    IF H$="N" OR H$="N" THEN 1060
920    !
930    PRINTER IS 706           ! TOGGLES PRINTER TO THERMAL PRINTER
940    PRINT ""
950    PRINT "USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION"
960    PRINT "HAS BEEN ENTERED FOR: ";D$
970    PRINT ""
980    PRINT "WIDTH =";W;"       NOTCH LENGTH =";A
990    PRINT "Bmax =";Bmax;"       Bmin =";Bmin
1000   PRINT "HALF SPAN =";Hs;" POISSON'S RATIO =";Nu
1010   PRINT "YIELD STRENGTH =";Ys;" ULTIMATE TS =";Uts
1020   PRINT "ELASTIC MODULUS =";E;" FLOW STRESS =";Fs
1030   PRINT ""
1040   PRINTER IS 1          ! TOGGLES PRINTER BACK TO CRT
1050   !
1060   PRINT CHR$(12)       ! CLEARS CRT
1070   !
1080   ! CONVERSION TO METRIC UNITS
1090   Conlen=25.4              ! 1in = 25.40mm
1100   Wm=W*Conlen
1110   Am=A*Conlen
1120   Bmaxm=Bmax*Conlen
1130   Bminm=Bmin*Conlen
1140   Hsm=Hs*Conlen
1150   Conpress=6.89475293      ! 1psi = 6.89475293kPa (HP PROGRAMING BOOK)
1160   Em=E*Conpress
```

```
1170  Ysm=Ys*Conpress
1180  Utsm=Uts*Conpress
1190  Fsm=Fs*Conpress
1200  !
1210  PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa)     for ";D$;" YIEL
DS:"
1220  PRINT "WIDTH =";Wm;"     NOTCH LENGTH =";Am
1230  PRINT "Bmax =";Bmaxm;"          Bmin =";Bminm
1240  PRINT "HALF SPAN =";Hsm;"     POISSON'S RATIO =";Nu
1250  PRINT "YIELD STRENGTH =";Ysm;"  UTILMATE TS =";Utsm
1260  PRINT "ELASTIC MODULUS =";Em;"  FLOW STRESS =";Fsm
1270  PRINT ""
1280  PRINT "DO YOU WISH TO HAVE A PRINT OUT OF THIS DATA?"
1290  INPUT G$
1300  IF G$="N" OR G$="NO" THEN 1410
1310  !
1320  PRINTER IS 706               ! TOGGLES TO THERMAL PRINTER
1330  PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: ";D$
1340  PRINT "WIDTH =";Wm;"          NOTCH LENGTH =";Am
1350  PRINT "Bmax =";Bmaxm;"     Bmin =";Bminm
1360  PRINT "YIELD STRENGTH =";Ysm;"  ULTIMATE TS =";Utsm
1370  PRINT "ELASTIC MODULUS =";Em;"  FLOW STRESS =";Fsm
1380  PRINT ""
1390  PRINTER IS 1                     ! TOGGLES PRINTER TO CRT
1400  !
1410  PRINT CHR$(12)                   ! CLEAR CRT
1420  !
1430  Flag3=0
1440  A1=A
1450  GOSUB Params
1460  !
1470  RETURN
1480  !
1490  !****************************************
1500  !
1510 New_a:      ! THIS ROUTINE COMPUTES NEW CRACK LENGTH AND NEW PARAMETERS
1520  !
1530  Beffm=Bmaxm-(Bmaxm-Bminm)^2/Bmaxm     ! B EFFECTIVE FROM ASTM E813-81
1540  D2=1                ! INITIALIZES COUNTER
1550  PRINT CHR$(12)    ! CLEARS CRT
1560  PRINT "THIS ROUTINE WILL OBTAIN CURRENT CRACK LENGTH"
1570  PRINT " AND NEW PARAMETERS FOR PRECRACKING."
1580  PRINT "BEFORE YOU CAN RUN THIS ROUTINE YOU MUST:"
1590  PRINT "     1. ENTER SPECIMEN DATA"
1600  PRINT "     2. ENTER CONVERSION DATA"
1610  PRINT "     3. SETUP MTS FOR MANUAL LOADING OF THE";
1620  PRINT "                SPECIMEN."
1630  PRINT " "
1640  PRINT "  ARE YOU READY?"
1650  INPUT H$
1660  IF H$="N" OR H$="NO" THEN 2450  ! RETURNS TO k-KEY SELECTION
1670  PRINT CHR$(12)        ! CLEARS CRT
1680  PRINT "YOU MAY LOAD AND UNLOAD SPECIMEN AS OFTEN AS  YOU LIKE -- BUT YOU M
UST REMAIN ";
1690  PRINT "BELOW CURRENT PMAX OF";Pmax;"Lbs"
1700  DIM Lod(2000),Defl(2000),Cod(2000)
1710  DIM Lodm(2000),Deflm(2000),Codm(2000)
1720  PRINT "WHEN YOU ARE READY TO BEGIN PRESS THE 'ENTER' OR 'CONTINUE' KEY."
1730  INPUT H$
1740  PRINT CHR$(12)          ! CLEARS CRT
```

```
1750  K=0                          ! USED AS COUNTER
1760  I=1                          ! USED AS INDEX
1770  Flag1=0
1780  Flag2=0
1790     WHILE Flag1=0    ! ESTABLISHES ONE LOAD-UNLOAD DATA TAKING LOOP
1800        GOSUB Data_acq
1810     END WHILE
1820     Flag2=0           ! RESETS FLAG2
1830     WHILE Flag2=0
1840        GOSUB Data_acq
1850     END WHILE
1860  !
1870  ! THIS SECTION CAN BE USED TO VIEW THE COLLECTED DATA BY REMOVING THE REMA
RK CHARACTER (!).
1880  ! FOR I=1 TO K
1890    ! PRINT USING 1960;I,Lodm(I),Deflm(I),Codm(I)
1900    ! IMAGE X,3D,4X,6D.D,4X,3D.7D,7X,3D.7D
1910  ! NEXT I
1920  ! WAIT 5
1930  K1=1
1940  K3=K
1950  GOSUB Slope        ! SLOPE = 1/COD COMPLIANCE
1960  GOSUB Crack_length  ! USES COD COMPLIANCE
1970  !
1980  A0(D2)=Crack1m/25.4    ! CONVERTS TO INCHES
1990  A1=A0(D2)
2000  !
2010  ! FIND 95% CONFIDENCE INTERVAL FOR CRACK LENGTH
2020    Stiffm=Stiffm+T9*U4
2030    GOSUB Crack_length
2040    Amax=Crack1m/25.4      ! CONVERTS TO INCHES
2050    Stiffm=Stiffm-2*T9*U4
2060    GOSUB Crack_length
2070    Amin=Crack1m/25.4      ! CONVERTS TO INCHES
2080  !
2090  !
2100  PRINT CHR$(12)      ! CLEARS CRT
2110  PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
2120  PRINT ""
2130  PRINT "CRACK LENGTH =";A0(D2);"in      FROM MEASUREMENT #";D2
2140  PRINT "WITH 95% CONFIDENCE INTERVAL FROM";Amin;" TO";Amax
2150  PRINT ""
2160  PRINT "USING COD COMPLIANCE OF:";Compl;"in/Lb    =";Compl m;"mm/N"
2170  PRINT "WITH A CORRELATION OF:";Correl;" FROM";K;"DATA POINTS"
2180  PRINT ""
2190  PRINT "DO YOU WANT A HARD COPY?"
2200  INPUT G$
2210  IF G$="N" OR G$="NO" THEN 2340
2220  !
2230  PRINTER IS 706       ! TOGGLES TO THERMAL PRINTER
2240  PRINT ""
2250  PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
2260  PRINT "CRACK LENGTH =";A0(D2);"in FROM MEASUREMENT #";D2
2270  PRINT "WITH 95%CONFIDENCE INTERVAL FROM";Amin;" TO";Amax;"in"
2280  PRINT "USING COD COMPLIANCE OF:";Compl;"in/Lb =";Complm;"mm/N"
2290  PRINT "WITH A CORRELATION OF:";Correl;"FROM";K;" DATA POINTS."
2300  PRINT ""
2310  PRINTER IS 1         ! TOGGLES PRINTER TO CRT
2320  !
```

```
2330  PRINT ""
2340  PRINT "   DO YOU WANT ANOTHER MEASUREMENT?"
2350  INPUT F$
2360  D2=D2+1          ! INCREMENTS COUNTER
2370  IF F$="Y" OR F$="YES" THEN 1670
2380  !
2390  IF A0(D2-1)>Opta THEN GOSUB End_precrack  ! PRECRACKING IS COMPLETE
2400  !
2410  IF A0(D2-1)>.4*Dela+A THEN Flag3=1     ! SETS FLAG INDICATING IN LAST 60% O
F PRECRACKING
2420  !
2430  GOSUB Params
2440  !
2450  RETURN
2460  !
2470  !****************************************
2480  !
2490 Data_acq:   ! DATA ACQUISITION ROUTINE
2500    OUTPUT Dvm:"VR5 AF1 AL3"
2510    !
2520    OUTPUT Dvm;"AI1 VT1"        ! READS LOAD
2530    ENTER Dvm:Lod(I)
2540    Lodm(I)=Lod(I)*Slm(1)
2550    !
2560    OUTPUT Dvm:"AI2 VT1"        ! READS COD
2570    ENTER Dvm:Cod(I)
2580    Codm(I)=Cod(I)*Slm(2)
2590    !
2600    OUTPUT Dvm;"AI3 VT1"        ! READS DEFLECTION
2610    ENTER Dvm:Defl(I)
2620    Deflm(I)=Defl(I)*Slm(3)
2630    !
2640    ! TEST  DATA TO BREAK OUT OF DATA ACQ LOOP
2650    !
2660    IF I=1 THEN 2720     ! SKIPS IF FIRST DATA POINT
2670    Lodiffm=Lodm(I)-Lodm(I-1)
2680       IF Lodiffm<-25.0 THEN Flag1=1     ! MUST BE UNLOADING
2690       IF Lodiffm>25.0 THEN Flag2=1      ! MUST BE RELOADING.
2700    Lodiffm=0
2710    !
2720    I=I+1        ! INCREMENTS INDEX
2730    !
2740    K=K+1        ! INCREMENT COUNTER
2750    !
2760    RETURN
2770    !
2780    !****************************************
2790    !
2800 Crack_length:   ! CALCULATES CRACK LENGTH USING HUDAK (DTNSRDC PROG)
2810    !  NOTE: THIS ROUTINE USES COD COMPLIANCE  METHOD VICE DEFLECTION COMPLIA
NCE.
2820    FOR I=1 TO 6
2830       READ Coef(I)
2840    NEXT I
2850    Compl m=1/Stiffm
2860    C=2*Wm*Beffm*Em*Complm/(Hsm*1000)
2870    C=1/(SQR(C)+1)
2880    G(1)=C
2890    FOR I=2 TO 5
2900       G(I)=G(I-1)*G(1)
```

```
2910    NEXT I
2920    F=Coef(1)
2930    FOR I=1 TO 5
2940       F=F+Coef(I+1)*G(I)
2950    NEXT I
2960    Cracklm=F*Wm
2970    RESTORE
2980    DATA 0.998265,-3.91662,-1.80596,32.31038,-44.15665.-52.67876
2990    !
3000    RETURN
3010    !
3020    !****************************************
3030    !
3040  Conv_data:     ! INPUTS CONVERSION DATA FOR MEASURING DEVICES
3050    PRINT CHR$(12)            ! CLEARS CRT
3060    PRINT "INPUT: LOAD RANGE, STRAIN RANGE, STROKE RANGE"
3070    PRINT ""
3080    PRINT "    (BY PERCENT ie. 10.20.50 OR 100)"
3090     INPUT Lr,Cr,Sr
3100    PRINT ""
3110    PRINT "LOAD RANGE = ";Lr
3120    PRINT "STRAIN (COD) RANGE = ";Cr
3130    PRINT "STROKE (DEFLECTION) RANGE = ";Sr
3140    Lmax=20000       ! MAX LOAD RANGE IN (lbs).
3150    Cmax=.200        ! MAX COD RANGE IN (in).
3160    Smax=5.0         ! MAX STROKE RANGE IN (in).
3170    V=-10             ! MAX VOLTAGE IN (volts).
3180    !
3190    ! MAXIMUM OPERATING POINTS ARE:
3200    Olmax=Lmax*Lr/100
3210    Ocmax=Cmax*Cr/100*(-1.0)  ! -1 CHANGES SIGN
3220    Osmax=Smax*Sr/100
3230    !
3240    ! CONVERSION CONSTANTS ARE: (ENGLISH UNITS)
3250    Sl(1)=Olmax/V
3260    Sl(2)=Ocmax/V
3270    Sl(3)=Osmax/V
3280    ! CONVERTING TO METRIC:
3290    Conlen=25.4                ! 25.4mm = 1in
3300    Conlb=4.448221615         ! 4.448221615N = 1lb      (HP PROGRAMING BOOK)
3310    Slm(1)=Sl(1)*Conlb
3320    Slm(2)=Sl(2)*Conlen
3330    Slm(3)=Sl(3)*Conlen
3340    !
3350    PRINT ""
3360    PRINT ""
3370    PRINT "YOUR ENTRIES HAVE PRODUCED THE FOLLOWING           CONVERSION DATA:
"
3380    PRINT ""
3390    PRINT "FOR LOAD: ";Slm(1);"NEWTON/VOLT   (";Sl(1);"Lbs/V)"
3400    PRINT ""
3410    PRINT "FOR COD: ";Slm(2);"mm/V   (";Sl(2);"in/V)"
3420    PRINT ""
3430    PRINT "FOR DEFLECTION: ";Slm(3);"mm/V (";Sl(3);"in/V)"
3440    PRINT ""
3450    PRINT "WOULD YOU LIKE A HARD COPY?"
3460    INPUT H$
3470    IF H$="N" OR H$="NO" THEN 3570
3480    !
3490    PRINTER IS 706            ! TOGGLES PRINTER
```

```
3500   PRINT ""
3510   PRINT "        CONVERSION DATA"
3520   PRINT "FOR LOAD:";S1m(1);"N/V   (";S1(1);"Lbs/V)"
3530   PRINT "FOR COD:";S1m(2);"mm/V   (";S1(2);"in/V)"
3540   PRINT "FOR DEFLECTION:";S1m(3);"mm/V   (";S1(3);"in/V)"
3550   PRINTER IS 1              ! TOGGLES PRINTER
3560   !
3570   PRINT CHR$(12)
3580   !
3590   RETURN
3600   !
3610   !****************************************
3620   !
3630 Slope:   ! LINEAR LEAST SQUARES FIT
3640   PRINT CHR$(12)          ! CLEAR CRT
3650   ! INITIALIZE VARIABLES
3660   Sumx=0      ! SUM OF X VALUES
3670   Sumx2=0     ! SUM OF X SQUARED VALUES
3680   Sumy=0      ! SUM OF Y VALUES
3690   Sumy2=0     ! SUM OF Y SQUARED VALUES
3700   Sumxy=0     ! SUM OF THE PRODUCT
3710   FOR I=K1 TO K3     ! K1=INDEX OF FIRST, K3=INDEX OF LAST DATA POINT USED.
3720     !
3730     X=Codm(I)
3740     Y=Lodm(I)
3750     !
3760     Sumx=Sumx+X
3770     Sumy=Sumy+Y
3780     Sumx2=Sumx2+X*X
3790     Sumy2=Sumy2+Y*Y
3800     Sumxy=Sumxy+X*Y
3810   NEXT I
3820   K3=K3-P2       ! USED TO CALCULATE NUMBER OF DATA POINTS WITHIN BOUNDS.
3830   K4=K3-K1+1          ! K4=TOTAL # DATA POINTS USED IN CALC
3840   Qa1=Sumx2-Sumx*Sumx/K4
3850   Qa2=Sumxy-Sumx*Sumy/K4
3860   Qa3=Sumy2-Sumy*Sumy/K4
3870   !
3880   M=Qa2/Qa1                ! SLOPE
3890   !
3900   IF M<0 THEN 4190    ! IF SLOPE < 0, BAD DATA
3910   !  FROM DTNSRDC PROGRAM
3920   Q1=(K4*Sumx2-Sumx^2)/(K4*(K4-1))
3930   Q2=(K4*Sumy2-Sumy^2)/(K4*(K4-1))
3940   Q3=(K4-1)*(Q2-M*M*Q1)/(K4-2)
3950   Q4=SQR(Q3/(Q1*(K4-1)))
3960   !
3970   B=(Sumy-M*Sumx)/K4      ! INTERCEPT
3980   !
3990   Correl=M*SQR(Q1/Q2)
4000   !
4010   Qa4=SQR(ABS((Sumy2-B*Sumy-M*Sumxy)/(K4-2)))
4020   Sigmab=Qa4/SQR(ABS(Qa1))
4030   Sigmam=Sigmab*SQR(Sumx2/K4)
4040   Stiffm=M                       ! STIFF = SLOPE
4050   Complm=1/M        ! COD COMPLIANCE = 1/SLOPE
4060   Compl=Complm*(4.448221615)/25.4  ! CONVERTS TO  in/LB
4070   !
4080   ! STUDENT t TEST
4090   U4=Q4
```

```
4100   T9=1.96
4110   IF K4>120 THEN 4170           ! RETURNS
4120   T9=2.1
4130   IF K4<20 THEN 4170            ! RETURNS
4140   N9=K4-2
4150   T9=N9/(-.617109+N9*.510239)
4160   !
4170   RETURN
4180   !
4190   PRINT "POOR DATA-- SLOPE < 0"
4200   M=333333.3
4210   Correl=0
4220   !
4230   RETURN
4240   !
4250   !****************************************
4260   !
4270 Params:      ! THIS ROUTINE WILL DETERMINE THE CURRENT MAX AND MIN LOAD FOR
FATIGUE PRECRACKING
4280   !
4290   ! NOTE THE USE OF ENGLISH UNITS DUE MTS READOUT BEING IN POUNDS.
4300   ! INITIALIZE VARIABLES
4310   Faw=0
4320   Pmax=0
4330   Pmin=0
4340   Delp=0
4350   Kmaxp=0
4360   Kminp=0
4370   Delk=0
4380   Delke=0
4390   !
4400   Opta=.6*W      ! OPTIMUM CRACK LENGTH
4410   Dela=Opta-Al   ! EXTENSION REQUIRED
4420   Dela50=Dela*(.5)+A    ! CRACK LENGTH AT 50% OF EXTENSION
4430   !
4440   Pmax=(4/3)*(Bmin*(W-Al)^2*Fs/(2*Hs))    ! FROM ASTM E813
4450   IF Flag3=1 THEN Pmax=(.4)*Pmax          ! MAX LOAD DURING LAST 50% OF PRECR
ACKING (ASTM E813)
4460   Pmin=Pmax-.95*Pmax       ! FROM ASTM E813
4470   Delp=Pmax-Pmin
4480   !
4490   ! DETERMINE Delk BASED ON P USING ASTM E399
4500   !
4510   Fawn=3*(Al/W)^.5*(1.99-(Al/W)*(1-Al/W)*(2.15-3.93*Al/W+2.7*(Al/W)^2))
4520   !
4530   Fawd=2*(1+2*Al/W)*(1-Al/W)^1.5
4540   !
4550   Faw=Fawn/Fawd
4560   !
4570   !
4580   Kmaxp=(Pmax*2*Hs/(Bmin*W^1.5))*Faw    ! FROM ASTM E399
4590   Kminp=(Pmin*2*Hs/(Bmin*W^1.5))*Faw    ! FROM ASTM E399
4600   Delk=Kmaxp-Kminp
4610   !
4620   ! DETERMINE Delke BASED ON MODULUS FROM ASTM E813
4630   IF Flag3=0 THEN Delke=40000          ! DURING EARLY EXTENSION
4640   IF Flag3=1 THEN Delke=(.001)*E       ! DURING LAST 50% OF PRECRACKING  [RE
F. ASTM E399 & E813]
4650   PRINT ""
```

```
4660   PRINT "BASED ON CURRENT INFORMATION:"
4670   PRINT ""
4680   PRINT "CURRENT CRACK LENGTH =";A1;"in"
4690   PRINT "OPTIMUM a0=";Opta;"in"
4700   PRINT "EXTENSION REQUIRED =";Dela
4710   PRINT "CRACK LENGTH AT 50% OF EXTENSION =";Dela50;"in"
4720   PRINT "Pmax =";Pmax;"Lbs  Pmin =";Pmin;"Lbs"
4730   PRINT "Kmaxp =";Kmaxp;"   Kminp =";Kminp
4740   PRINT "DELTA_K =";Delk;"in^.5"
4750   PRINT "DELTA_KE =";Delke;"in^.5"
4760   PRINT "FAW =";Faw        ! SERVES AS A CHECK
4770   PRINT ""
4780   PRINT "IF Delk > Delke. Pmax MUST BE DECREASED"
4790   IF Delk<Delke THEN 4900     ! SKIP IF OKAY
4800   ! COMPUTE NEW Pmax
4810   Delp1=(Delke/Faw/(2*Hs)*Bmin*W^1.5)
4820   Pmax1=Delp1/.95
4830   Pmin1=Pmax1-.95*Pmax1
4840   Kmax1=(Pmax1*2*Hs/(Bmin*W^1.5))*Faw
4850   PRINT "THE NEW Pmax BASED ON Delke IS:";Pmax1;"Lbs"
4860   PRINT "NEW Pmin =";Pmin1;"Lbs"
4870   PRINT "NEW DELTA_P =";Delp1;"Lbs"
4880   PRINT "NEW Kmax =";Kmax1
4890   !
4900   PRINT "   DO YOU WANT A HARD COPY?"
4910   INPUT H$
4920   IF H$="N" OR H$="NO" THEN 5080
4930   PRINTER IS 706       ! TOGGLES PRINTER
4940   PRINT "BASED ON CURRENT INFORMATION FOR ";D$;":"
4950   PRINT ""
4960   PRINT "CURRENT CRACK LENGTH =";A1;"in"
4970   PRINT "OPTIMUN CRACK LENGTH =";Opta;"in"
4980   PRINT "EXTENSION REQUIRED =";Dela;"in"
4990   PRINT "CRACK LENGTH AT 50% OF EXTENSION =";Dela50;"in"
5000   PRINT "Pmax =";Pmax;"Lbs  Pmin =";Pmin;"Lbs"
5010   PRINT "Delp =";Delp;"Lbs  Kmax =";Kmaxp
5020   PRINT "DELTA_K =";Delk;"in^.5  DELTA_KE =";Delke;"in^.5"
5030   IF Delk<Delke THEN 5090
5040   PRINT ""
5050   PRINT "NEW LOADS  BASED ON DELTA_KE ARE:"
5060   PRINT "Pmax =";Pmax1;"Lbs  Pmin =";Pmin1;"Lbs"
5070   PRINT "DELTA_P =";Delp1;"Lbs   Kmax =";Kmax1
5080   PRINT ""
5090   PRINTER IS 1       ! TOGGLES PRINTER TO CRT
5100   PRINT ""
5110   PRINT "MAKE THE NECESSARY ADJUSTMENTS BEFORE CONTINUING."
5120   PRINT "WHEN COMPLETED PRESS `CONTINUE`."
5130   INPUT C$
5140   !
5150   RETURN
5160   !
5170   !****************************************
5180   !
5190 A_table:       ! PRODUCES TABULATED VALUES FOR LOAD vs COD VALUES AT VARIOU
S CRACK LENGTHS
5200   !
5210   PRINT "BEFORE YOU CAN RUN THIS SUBROUTINE YOU MUST ENTER:"
5220   PRINT "       1.  SPECIMEN DATA"
5230   PRINT "       2.  CONVERSION DATA"
```

```
5240   PRINT ""
5250   PRINT "ARE YOU READY?"
5260   INPUT H$
5270   IF H$="N" OR H$="NO" THEN 5550   ! RETURNS TO k-KEY SELCETION
5280   !
5290   Beff=Bmax-(Bmax-Bmin)^2/Bmax     ! IAW ASTM E813-81
5300   PRINT "BEFF =";Beff
5310   !
5320   ! USING CRACK LENGTH EQUATION FROM DTNSRDC PROGRAM CALC CRACK LENGTH FOR
VARIOUS VALUES OF U
5330   A00=.998265
5340   A1=-3.81662
5350   A2=-1.80596
5360   A3=32.31038
5370   A4=-44.15665
5380   A5=-52.67876
5390   FOR U=.07 TO .155 STEP .005
5400      Ar=A00+A1*U+A2*U^2+A3*U^3+A4*U^4+A5*U^5
5410      Ckl=Ar*W
5420      PRINTER IS 706    ! TOGGLES TO THERMAL PRINTER
5430      PRINT "U =";U
5440      PRINT "a/W =";Ar;"in  CRACK LENGTH =";Ckl;"in"
5450      PRINT "LOAD (lbs)      COD (in)       COD (Volts)"
5460      FOR Lod1=200 TO 1800 STEP 100
5470         C=Beff*W*E*2/Hs
5480         Cod1=Lod1*((1-U)/U)^2/C
5490         Codv=Cod1/S1(2)
5500         PRINT Lod1,Cod1,Codv
5510      NEXT Lod1
5520   NEXT U
5530   PRINTER IS 1     ! RETURNS TO USING CRT AS PRINTER
5540   !
5550   RETURN
5560   !
5570   !****************************************
5580   !
5590 End_precrack:        ! END OF PRECRACKING
5600   !
5610   PRINT "    PRECRACKING IS COMPLETED!"
5620   PRINT ""
5630   PRINT "FINAL CRACK LENGTH =";A0(D2-1)
5640   PRINT "CORRELATION OF DATA =";Correl
5650   PRINT ""
5660   PRINT "    REMOVE SPECIMEN FROM MTS."
5670   !
5680   END
```

APPENDIX E

J_INTGL LISTING

```
10    ! J-INTEGRAL FRACTURE TOUGHNESS PROGRAM
20    ! FOR THREE POINT BEND SPECIMEN.  THIS
30    ! PROGRAM INCORPORATES THE USE OF THE
40    ! FOLLOWING EQUIPMENT:
50    !      1. HP-9826 COMPUTER
60    !      2. HP-3497A DATA ACQUISITION SYSTEM
70    !      3. HP-3437A SYSTEM VOLTMETER
80    !      4. HP-2671G THERMAL PRINTER
90    !      5. HP-7225B PLOTTER
100   !
110   ! THIS PROGRAM WAS WRITTEN BY:
120   !      LCDR W. K. TRITCHLER, USN
130   ! VERSION 1.0      DATE 11/83
140   !
150   !
160   !
170   COM /J_intgl/ F1
180   !
190   ! DIM Lod(8000),Defl(8000),Cod(8000)
200   ! NOTE: Lod, Defl AND Cod ARE ACTUALLY DIMENSIONED IN Initial_a ROUTINE
210   ! Lod(I) = LOAD
220   ! Defl(I) = DEFLECTION
230   ! Cod(I) = CRACK OPENING DISPLACEMENT (COD)
240   !
250   DIM A0(50),Amin0(50),Amax0(50),Compl0(50),Correl0(50)
260   DIM Area9(100),A1(100),Coef(6),G(6)
270   DIM J9(100),Delta_a(100),Mdefl(100)
280   DIM Data$(1:4)[10]
290   DUMP DEVICE IS 706     ! THERMAL PRINTER ADDRESS
300   Dvm=709                ! DATA ACQUISITION ADDRESS
310   CLEAR Dvm
320   PRINT CHR$(12)        ! CLEARS CRT
330   PRINT ""
340   PRINT "              J-INTEGRAL TEST PROGRAM"
350   PRINT "                    VERSION 1.0"
360   PRINT "           WRITTEN BY LCDR W.K. TRITCHLER"
370   PRINT ""
380   PRINT "                PLEASE SELECT A k-KEY"
390   !
400   !****************************************
410 Begin: !
420   ON KEY 0 LABEL "SPEC_DATA" GOSUB Spec_data
430   ON KEY 1 LABEL "CONV_DATA" GOSUB Conv_data
440   ON KEY 2 LABEL "DAT_FILE" GOSUB Data_file
450   ON KEY 3 LABEL "PLOTTER" GOSUB Setup_plotter
460   ON KEY 4 LABEL "GCLEAR" GOSUB Gclr
470   ON KEY 5 LABEL "a0" GOSUB Initial_a
480   ON KEY 7 LABEL "START" GOSUB Main_prog
490   !(*) ON KEY 8 LABEL "R-CURVE" GOSUB R_curve
500   ! (SEE NOTES ON (*) IN R_curve ROUTINE
510   ON KEY 9,4 CALL Stop_test
520   !
530   !****************************************
540   !
550 Spin:     ! WAITS FOR KEY INPUT
560   GOTO Spin
570   !
580   !****************************************
590   !
```

```
600 Gclr:     ! GRAPHICS SCREEN CLEAR
610   ! THIS ROUTINE ALLOWS SINGLE KEY STROKE TO REMOVE A GRAPHICS DISPLAY FROM
CRT
620   GCLEAR
630   RETURN  ! RETURNS TO k-KEY SELECTION
640   !
650   !****************************************
660   !
670 Spec_data:   ! INPUTS REQUIRED SPECIMEN DATA
680   PRINT CHR$(12)        ! CLEARS CRT
690   PRINT "INPUT SPECIMEN IDENTIFICATION (ID):"
700   INPUT D$
710   PRINT ""
720   PRINT "J-INTEGRAL TEST for ";D$
730   PRINT ""
740   PRINT "INPUT SPECIMEN DATA USING ENGLISH UNITS (LBS.      INCHES, etc.)"
750   PRINT ""
760   PRINT "WHAT IS THE SPECIMEN'S WIDTH, NOTCH LENGTH, Bmax,  Bmin (THICKNESS)
?"
770   INPUT W,A,Bmax,Bmin
780   PRINT ""
790   PRINT "WHAT IS THE SPECIMEN'S HALF SPAN AND POISSON'S     RATIO?"
800   INPUT Hs,Nu
810   PRINT ""
820   PRINT "WHAT IS THE SPECIMEN'S ELASTIC MODULUS, YIELD      STRENGTH AND ULT
IMATE STRENGTH?"
830   INPUT E,Ys,Uts
840   PRINT CHR$(12)             ! CLEARS CRT
850   Fs=(Ys+Uts)/2
860   PRINT "USING ENGLISH UNITS (in.lbs.psi)"
870   PRINT "THE FOLLOWING HAS BEEN ENTERED for: ";D$
880   PRINT "WIDTH =";W;"    NOTCH LENGTH =";A
890   PRINT "Bmax =";Bmax;"          Bmin =";Bmin
900   PRINT "HALF SPAN =";Hs;"   POISSON'S RATIO =";Nu
910   PRINT "YIELD STRENGTH =";Ys;"  ULTIMATE TS =";Uts
920   PRINT "ELASTIC MODULUS =";E;"    FLOW STRESS =";Fs
930   PRINT ""
940   PRINT "THIS PROGRAM ALLOWS NO EASY RECOVERY, IF ANY DATA IS INCORRECT YOU
MUST RE-ENTER ";
950   PRINT "EVERYTHINC."
960   PRINT ""
970   PRINT "IS ALL DATA CORRECT?"
980   INPUT H$
990   IF H$="NO" OR H$="N" THEN 670    ! REPEATS Spec_data
1000  PRINT ""
1010  PRINT "DO YOU WANT A HARD COPY?"
1020  INPUT H$
1030  IF H$="N" OR H$="N" THEN 1180
1040  !
1050  PRINTER IS 706          ! TOGGLES PRINTER TO THERMAL PRINTER
1060  PRINT ""
1070  PRINT "USING ENGLISH UNITS (in.lbs.psi) THE FOLLOWING INFORMATION"
1080  PRINT "HAS BEEN ENTERED FOR: ";D$
1090  PRINT ""
1100  PRINT "WIDTH =";W;"        NOTCH LENGTH =";A
1110  PRINT "Bmax =";Bmax;"         Bmin =";Bmin
1120  PRINT "HALF SPAN =";Hs;" POISSON'S RATIO =";Nu
1130  PRINT "YIELD STRENGTH =";Ys;" ULTIMATE TS =";Uts
1140  PRINT "ELASTIC MODULUS =";E;" FLOW STRESS =";Fs
1150  PRINT ""
```

```
1160  PRINTER IS 1          ! TOGGLES PRINTER BACK TO CRT
1170  !
1180  PRINT CHR$(12)        ! CLEARS CRT
1190  !
1200  ! CONVERSION TO METRIC UNITS
1210  Conlen=25.4               ! 1in = 25.40mm
1220  W=W*Conlen
1230  A=A*Conlen
1240  Bmax=Bmax*Conlen
1250  Bmin=Bmin*Conlen
1260  Hs=Hs*Conlen
1270  Conpress=6.89475293        ! 1psi = 6.89475293kPa (HP PROGRAMING BOOK)
1280  E=E*Conpress
1290  Ys=Ys*Conpress
1300  Uts=Uts*Conpress
1310  Fs=Fs*Conpress
1320  !
1330  PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa)      for ";D$;" YIEL
DS:"
1340  PRINT "WIDTH =";W;"    NOTCH LENGTH =";A
1350  PRINT "Bmax =";Bmax;"          Bmin =";Bmin
1360  PRINT "HALF SPAN =";Hs;"     POISSON'S RATIO =";Nu
1370  PRINT "YIELD STRENGTH =";Ys;"  UTILMATE TS =";Uts
1380  PRINT "ELASTIC MODULUS =";E;"  FLOW STRESS =";Fs
1390  PRINT ""
1400  PRINT "DO YOU WISH TO HAVE A PRINT OUT OF THIS DATA?"
1410  INPUT G$
1420  IF G$="N" OR G$="NO" THEN 1540
1430  !
1440  PRINTER IS 706              ! TOGGLES TO THERMAL PRINTER
1450  PRINT "CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: ";D$
1460  PRINT "WIDTH =";W;"         NOTCH LENGTH =";A
1470  PRINT "Bmax =";Bmax;"      Bmin =";Bmin
1480  PRINT "HALF SPAN =";Hs;"     POISSON'S RATIO =";Nu
1490  PRINT "YIELD STRENGTH =";Ys;"  ULTIMATE TS =";Uts
1500  PRINT "ELASTIC MODULUS =";E;"  FLOW STRESS =";Fs
1510  PRINT ""
1520  PRINTER IS 1                    ! TOGGLES PRINTER TO CRT
1530  !
1540  PRINT CHR$(12)                  ! CLEAR CRT
1550  !
1560  RETURN        ! RETURNS TO k-KEY SELECTION
1570  !
1580  !******************************************
1590  !
1600 Setup_plotter: ! SET UP INTERACTIVE PLOTTER
1610  ! YOU CAN CHOOSE BETWEEN THREE DIFFERENT PLOTS
1620  ! (P vs COD, P vs DEFLECTION, OR J vs DELTA_A)
1630  PRINT CHR$(12)              ! CLEARS CRT
1640  DIM T$[80],X$[80],Y$[80]
1650  GCLEAR
1660  GINIT
1670  GRAPHICS ON
1680  PLOTTER IS 3,"INTERNAL"       ! PLOTS ON CRT FOR VIEWING BEFORE SENDING TO
 HP-7225B PLOTTER
1690  PRINT "TYPE OF PLOT:"
1700  PRINT "     1. LOAD vs COD"
1710  PRINT "     2. LOAD vs DEFLECTION"
1720  PRINT "     3. J vs CRACK EXTENSION"
1730  PRINT "ENTER THE # OF THE PLOT YOU DESIRE"
```

```
1740  INPUT C2
1750  PRINT ""
1760  PRINT ""
1770  IF C2=1 THEN 1810
1780  IF C2=2 THEN 1860
1790  IF C2=3 THEN 1910
1800  PRINT ""
1810  T$="PLOT of LOAD vs COD for "&D$
1820  PRINT T$
1830  X$="COD (mm)"
1840  Y$="LOAD (N)"
1850  GOTO 1950
1860  T$="PLOT of LOAD vs DEFLECTION for "&D$
1870  PRINT T$
1880  X$="DEFLECTION (mm)"
1890  Y$="LOAD (N)"
1900  GOTO 1950
1910  T$="PLOT of J vs CRACK EXTENSION for "&D$
1920  PRINT T$
1930  X$="DELTA_a  (mm)"
1940  Y$="J  (kJ/m^2)"
1950  PRINT ""
1960  PRINT "USING METRIC UNITS (mm,N,kJ/m^2,etc):"
1970  PRINT "ENTER HERE THE Xmin,Xmax,Ymin,Ymax"
1980   INPUT X1(C2),X2(C2),Y1(C2),Y2(C2)
1990  X3=X2(C2)-X1(C2)
2000  Y3=Y2(C2)-Y1(C2)
2010  VIEWPORT 13,100*RATIO,10,90
2020  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2030  PRINT ""
2040  PRINT "INPUT DELTA_X AND DELTA_Y LABEL INTERVAL"
2050  PRINT "FOR THE TWO AXES:"
2060   INPUT X4,Y4
2070  PRINT ""
2080  PRINT "DO YOU WISH TO HAVE A GRID OVERLAY?"
2090  INPUT G$
2100  IF G$="NO" OR G$="N" THEN 2140
2110  PRINT ""
2120  PRINT "INPUT GRID LINES PER DELTA LABEL:"
2130  INPUT B0
2140  PRINT "PRESS 'ENTER' TO PLOT"
2150  INPUT H$
2160  PRINT CHR$(12)     ! CLEARS CRT <------------
2170  IF G$="NO" OR G$="N" THEN 2310
2180  FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
2190     MOVE I,Y1(C2)
2200     DRAW I,Y2(C2)
2210  NEXT I
2220  FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
2230     MOVE X1(C2),I
2240     DRAW X2(C2),I
2250  NEXT I
2260  GOTO 2320
2270  IF G$="Y" OR G$="YES" THEN 2320
2280  MOVE X2(C2),Y1(C2)
2290  DRAW X2(C2),Y2(C2)
2300  DRAW X1(C2),Y2(C2)
2310  CLIP ON
2320  AXES X4,Y4,X1(C2),Y1(C2)
2330  CLIP OFF
```

```
2340  VIEWPORT 13,100*RATIO,5,90
2350  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2360  LORG 4
2370  CSIZE 3,.6           ! LABELS X DIGITS
2380  FOR X=X1(C2) TO X2(C2) STEP X4
2390     CLIP OFF
2400     MOVE X,Y1(C2)
2410     CLIP OFF
2420     LABEL USING "K";X
2430  NEXT X
2440  VIEWPORT 4,100*RATIO,10,90
2450  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2460  LORG 2               ! LABELS Y DIGITS
2470  FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2480     CLIP OFF
2490     MOVE X1(C2),Y
2500     CLIP OFF
2510     LABEL USING "K";Y
2520  NEXT Y
2530  VIEWPORT 0,RATIO*100,0,100
2540  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2550  CSIZE 5
2560  LORG 6               ! PLOTS TITLE
2570     MOVE X2(C2)/2,Y2(C2)
2580     LABEL T$
2590  DEG
2600  LDIR 90
2610  CSIZE 4,.7
2620     MOVE X1(C2),Y2(C2)/2
2630     LABEL Y$          ! PLOTS Y-AXIS LABEL
2640  LORG 4
2650  LDIR 0
2660     MOVE X2(C2)/2,Y1(C2)
2670     LABEL X$          ! PLOTS X-AXIS LABEL
2680  !
2690  PRINT ""
2700  PRINT ""
2710  PRINT ""
2720  PRINT ""
2730  PRINT "       IS THE PLOT (AXES AND LABELS) OK?"
2740  PRINT ""
2750  PRINT "             NOTE:  IF YOU ANSWER YES OR Y"
2760  PRINT "                    PLOT WILL BE PRODUCED"
2770  PRINT "                    ON EXTERNAL PLOTTER."
2780  INPUT F$
2790  IF F$="N" OR F$="NO" THEN GOSUB Setup_plotter    ! REDO PLOTTER SETUP
2800  !
2810  GCLEAR               ! CLEARS PLOT FROM CRT
2820  !
2830  GOSUB Ext_plotter    ! SENDS PLOT TO PLOTTER
2840  !
2850  PENUP
2860  MOVE 0,0
2870  !
2880  RETURN           ! RETURNS TO k-KEY SELECTION OR R_curve ROUTINE
2890  !
2900  !****************************************
2910  !
2920 Ext_plotter:  ! DUMPS PLOTTER SETUP TO EXTERNAL HP-7225B PLOTTER
2930  !
```

```
2940  PLOTTER IS 705,"HPGL"
2950  VIEWPORT 13,100*RATIO,10,90
2960  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2970  IF G$="NO" OR G$="N" THEN 3080
2980  FOR I=X4/80+X1(C2) TO X2(C2) STEP X4/80
2990     MOVE I,Y1(C2)
3000     DRAW I,Y2(C2)
3010  NEXT I
3020  FOR I=Y4/80+Y1(C2) TO Y2(C2) STEP Y4/80
3030     MOVE X1(C2),I
3040     DRAW X2(C2),I
3050  NEXT I
3060  GOTO 3120
3070  IF G$="Y" OR G$="YES" THEN 3120
3080  MOVE X2(C2),Y1(C2)
3090  DRAW X2(C2),Y2(C2)
3100  DRAW X1(C2),Y2(C2)
3110  CLIP ON
3120  AXES X4,Y4,X1(C2),Y1(C2)
3130  CLIP OFF
3140  VIEWPORT 13,100*RATIO,5,90
3150  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3160  LORG 4
3170  CSIZE 3,.6            ! SIZE OF DIGITS
3180  FOR X=X1(C2) TO X2(C2) STEP X4
3190     CLIP OFF
3200     MOVE X,Y1(C2)
3210     CLIP OFF
3220     LABEL USING "K";X      ! LABELS X-AXIS
3230  NEXT X
3240  VIEWPORT 4,100*RATIO,10,90
3250  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3260  LORG 2
3270  FOR Y=Y1(C2) TO Y2(C2) STEP Y4
3280     CLIP OFF
3290     MOVE X1(C2),Y
3300     CLIP OFF
3310     LABEL USING "K";Y      ! LABELS Y-AXIS
3320  NEXT Y
3330  VIEWPORT 0,100*RATIO,0,100
3340  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3350  CSIZE 5                    ! TITLE SIZE
3360  LORG 6
3370     MOVE X2(C2)/2,Y2(C2)
3380     LABEL T$                ! PRINTS TITLE
3390  DEG
3400  LDIR 90
3410  CSIZE 4,.7
3420     MOVE X1(C2),Y2(C2)/2
3430     LABEL Y$              ! PRINTS Y-AXIS TITLE
3440  LORG 4
3450  LDIR 0
3460     MOVE X2(C2)/2,Y1(C2)
3470     LABEL X$              ! PRINTS X-AXIS TITLE
3480  PENUP
3490  MOVE 0,0
3500  !
3510  RETURN           ! RETURNS TO Setup_plotter
3520  !
3530  !*****************************************
```

```
3540  !
3550 Initial_a:   ! ESTIMATES INITIAL CRACK LENGTH
3560  Beff=Bmax-(Bmax-Bmin)^2/Bmax      ! USES B(EFFECTIVE) FROM ASTM E813-81
3570  D2=1                    ! INITIALIZES COUNTER
3580  PRINT CHR$(12)          ! CLEARS CRT
3590  PRINT "BEFORE YOU CAN RUN THIS ROUTINE YOU MUST:"
3600  PRINT "     1. ENTER SPECIMEN DATA"
3610  PRINT "     2. ENTER CONVERSION DATA"
3620  PRINT "     3. SET UP PLOTTER"
3630  PRINT "     4. CREATE DATA FILE"
3640  PRINT ""
3650  PRINT "ARE YOU READY?"
3660  INPUT H$
3670  IF H$="N" OR H$="NO" THEN 5070   ! RETURNS TO KEY SELECTION SCREEN
3680  PRINT CHR$(12)                   ! CLEARS CRT
3690  PRINT "THIS ROUTINE WILL OBTAIN THE INITIAL CRACK LENGTH AFTER FATIGUE PRE
-CRACKING."
3700  PRINT ""
3710  PRINT "YOU MAY LOAD AND UNLOAD THE SPECIMEN AS OFTEN AS  YOU LIKE -- BUT Y
OU MUST REMAIN ";
3720  PRINT "ON THE LINEAR      PORTION OF THE CURVE!"
3730  PRINT ""
3740  PRINT "NOTE:  THE MTS SHOULD BE IN 'STROKE' CONTROL"
3750  PRINT "       AT A VERY SLOW INVERTED RAMP FUNCTION"
3760  PRINT "       RATE OR YOU MAY DO THIS WITH MANUAL LOAD"
3770  PRINT "       CONTROL."
3780  PRINT ""
3790  !
3800  PRINT "WOULD YOU LIKE AN ESTIMATE OF Pmax (Lbs)?"
3810  INPUT E$
3820  IF E$="N" OR E$="NO" THEN 4060  ! SKIPS Pmax CALC
3830  !
3840  PRINT "YOU MUST PROVIDE AN ESTIMATE OF CURRENT CRACK      LENGTH"
3850  PRINT "INPUT YOUR ESTIMATE IN INCHES."
3860  INPUT Aest
3870  ! CONVERT ALL DIMENSIONS BACK TO ENGLISH UNITS.
3880  ! a0 IS SUFFIX ON ALL VARIABLES FOR THIS CALC.
3890  Beffa0=Beff/Conlen
3900  Wa0=W/Conlen
3910  Blig=(Wa0-Aest)          ! ESTIMATED LENGTH OF UNBROKEN LIGAMENT IN INCHES
3920  Fsa0=Fs/Conpress
3930  Hsa0=Hs/Conlen
3940  Pla0=.533*Beffa0*Blig^2*Fsa0/(2*Hsa0)
3950  PRINT "AN ESTIMATE OF Pmax IS";Pla0
3960  PRINT "Pmax ESTIMATES THE POINT AT WHICH THE CURVE"
3970  PRINT "BECOMES NONLINEAR, IAW ASTM E813-81"
3980  !
3990  PRINTER IS 706   ! TOGGLES PRINTER
4000  PRINT ""
4010  PRINT "GIVEN a=";Aest;"inches THEN:"
4020  PRINT "   Pmax=";Pla0;"Lbs FROM ASTM E813-81"
4030  PRINT ""
4040  PRINTER IS 1
4050  !
4060  DIM Lod(8000),Defl(8000),Cod(8000)
4070  !
4080  ! ASSIGN DEFL CORRECTION COEF USED IN Data_acq AND Take_data ROUTINES
4090  ! THIS USES A 4th ORDER POLYNOMIAL FIT OF RECORDED DATA ON THE MTS SYSTEM'
S COMPLIANCE
4100  !
```

```
4110  Corr(1)=5.798E-5
4120  Corr(2)=4.7419E-6
4130  Corr(3)=-2.803E-9
4140  Corr(4)=1.471E-12
4150  Corr(5)=-2.7741E-16
4160  !
4170  PRINT ""
4180  PRINT "WHEN YOU ARE READY TO BEGIN PRESS THE 'ENTER' KEY."
4190  INPUT H$
4200  PRINT CHR$(12)        ! CLEARS CRT
4210  K=0             ! USED AS A COUNTER
4220  I=1             ! USED AS INDEX
4230  Flag1=0     ! NOTE: FLAG1 AND FLAG2 ARE RESET
4240  Flag2=0     ! IN Data_acq ROUTINE
4250     WHILE Flag1=0      ! ESTABLISHES ONE LOAD-UNLOAD DATA TAKING LOOP
4260        GOSUB Data_acq
4270     END WHILE
4280     Flag2=0            !  RESETS FLAG2
4290     WHILE Flag2=0
4300        GOSUB Data_acq
4310     END WHILE
4320   PENUP
4330   ! THIS SECTION CAN BE USED TO VIEW THE COLLECTED DATA BY REMOVING THE REM
ARK CHARACTER (!).
4340   ! FOR I=1 TO K
4350      ! PRINT USING 3780;I,Lod(I),Defl(I),Cod(I)
4360      ! IMAGE X,3D,4X,6D.D,4X,3D.7D,7X,3D.7D
4370   ! NEXT I
4380  ! WAIT 5
4390  K1=1
4400  K3=K
4410  GOSUB Slope              ! SLOPE = 1/COD COMPLIANCE
4420  Correl0(D2)=Correl      ! SAVES CURRENT CORRELATION COEFFICIENT IN AN ARRAY
4430  !
4440  Compl0(D2)=Compl        ! SAVES CURRENT COMPLINACE VALUE IN AN ARRAY
4450  !
4460  GOSUB Crack_length      ! USES COD COMPLIANCE
4470  !
4480  A0(D2)=Crckl            ! SAVE THE LAST a0 MEASUREMENT OBTAINED IN AN ARRAY
4490  !
4500  !  FIND 95% CONFIDENCE INTERVAL FOR a0
4510      Stiff=Stiff+T9*U4
4520      GOSUB Crack_length
4530      Amax0(D2)=Crckl
4540      Stiff=Stiff-2*T9*U4
4550      GOSUB Crack_length
4560      Amin0(D2)=Crckl
4570  !
4580  !
4590  PRINT CHR$(12)           ! CLEARS CRT
4600  PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
4610  PRINT ""
4620  PRINT "INITIAL CRACK LENGTH (a0) =";A0(D2);"mm               FROM MEASUREME
NT #";D2
4630  PRINT ""
4640  PRINT "WITH 95% CONDIFENCE INTERVAL ON a FROM";Amin0(D2);" TO";Amax0(D2);"
mm"
4650  PRINT ""
4660  PRINT "USING COD COMPLIANCE OF:";Compl0(D2);"mm/N"
4670  PRINT "WITH A CORRELATION OF:";Correl0(D2);"FROM";K;"DATA POINTS."
```

```
4680  PRINT ""
4690  PRINT "DO YOU WANT A HARD COPY?"
4700  INPUT H$
4710  IF H$="N" OR H$="NO" THEN 4830
4720  !
4730  PRINTER IS 706             ! TOGGLES PRINTER
4740  PRINT ""
4750  PRINT "THE FOLLOWING INFORMATION HAS BEEN OBTAINED:"
4760  PRINT "INITIAL CRACK LENGTH =";A0(D2);"mm FROM MEASUREMENT #";D2
4770  PRINT "WITH 95% CONFIDENCE INTERVAL FROM";Amin0(D2);" TO";Amax0(D2);"mm"
4780  PRINT "USING COD COMPLIANCE OF:";Compl0(D2);"mm/N"
4790  PRINT "WITH A CORRELATION OF:";Correl0(D2);"FROM";K;"DATA POINTS."
4800  PRINT ""
4810  PRINTER IS 1             ! TOGGLES PRINTER
4820  !
4830  D2=D2+1                    ! INCREMENT COUNTER
4840  PRINT ""
4850  PRINT "DO YOU WANT ANOTHER a0 MEASUREMENT?"
4860  INPUT G$
4870  IF G$="Y" OR G$="YES" THEN 4060
4880  !
4890  PRINT "INPUT THE NUMBER (#) OF THE a0 MEASUREMENT YOU    WISH TO USE AND S
TORE."
4900  PRINT "     NOTE: ONLY THIS SET OF DATA ARE"
4910  PRINT "           STORED ON DISK."
4920  INPUT D2
4930  !
4940  A1=A0(D2)     ! ASSIGNS A1 TO DESIRED A0(D2) VALUE
4950  ! NOTE: A1 IS USED IN Main_prog AS INITIAL CRACK LENGTH VALUE
4960  !
4970  PRINT ""
4980  PRINT "YOU HAVE SELECTED MEASUREMENT #";D2
4990  PRINT "       ARE YOU SURE?"
5000  INPUT P$
5010  ! NOTE: ONLY THIS a0 MEASUREMENT IS STORED ON DISK
5020  !
5030  IF P$="N" OR P$="NO" THEN 4890     ! ALLOWS CORRECTION
5040  K2=0                  ! K2 IS UNLOADING COUNTER THIS WILL ENSURE CORRECT DAT
A IS STORED
5050    GOSUB Stor_data    !  <-----------***  WRITES ON DISK
5060  !
5070  PRINT CHR$(12)
5080  !
5090  !
5100  RETURN          ! RETURNS TO k-KEY SELECTION
5110  !
5120  !****************************************
5130  !
5140 Data_acq:    ! DATA ACQUISITION ROUTINE
5150    OUTPUT Dvm;"VR5 AF1 AL3"
5160    !
5170    OUTPUT Dvm;"AI1 VT1"        ! READS LOAD
5180    ENTER Dvm;Lod(I)
5190    Lod(I)=Lod(I)*S1(1)
5200    !
5210    OUTPUT Dvm;"AI2 VT1"        ! READS COD
5220    ENTER Dvm;Cod(I)
5230    Cod(I)=(Cod(I))*S1(2)
5240    ! NOTE: COD IS CALIBRATED ONLY FORM 0.475 TO 0.625 INCHES (MAX COD IS 0.1
5 INCHES)
```

```
5250    !
5260    OUTPUT Dvm;"AI3 VT1"        ! READS DEFLECTION
5270    ENTER Dvm;Defl(I)
5280    Defl(I)=Defl(I)*S1(3)
5290    !
5300    GOSUB Correct_defl        ! DETERMINE DEFL CORRECTION FACTOR
5310    !
5320    Defl(I)=Defl(I)-Totcor
5330    !
5340    !
5350    !    PLOT THE DATA POINT
5360    VIEWPORT 13,100*RATIO,10,90
5370    WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
5380    IF C2=2 THEN 5410
5390       PLOT Cod(I),Lod(I)
5400    GOTO 5420
5410       PLOT Defl(I),Lod(I)
5420    !
5430    ! TAKE DATA FOR ONE COMPLETE LOADING AND UNLOADING
5440    IF I=1 THEN 5520          ! SKIPS TEST ON THE FIRST DATA POINT
5450    !
5460    ! TEST DATA
5470    Lodiff=Lod(I)-Lod(I-1)
5480       IF Lodiff<-25.0 THEN Flag1=1    ! MUST BE    UNLOADING
5490       IF Lodiff>25.0 THEN Flag2=1     ! MUST BE   LOADING
5500    Lodiff=0.
5510    !
5520    I=I+1        ! INCREMENTS INDEX
5530    !
5540    K=K+1        ! INCREMENT COUNTER
5550    !
5560    RETURN       ! RETURNS TO Initial_a ROUTINE
5570    !
5580    !*****************************************
5590 Correct_defl:       ! THIS ROUTINE CALCULATES THE DEFLECTION CORRECTION FACT
OR
5600    !
5610    ! CORRECTION FACTOR IS REQUIRED TO ACCOUNT FOR SYSTEM COMPLIANCE
5620    ! A 4TH ORDER POLYNOMIAL FIT WAS PREVIOUSLY DETERMINED.
5630    !
5640    !      NOTE:  **********************
5650    ! THE 5 CORRECTION COEFFICIENTS CORR(I) WERE ASSIGNED IN Initial_a ROUTIN
E TO SPEED UP PROG.
5660    !         **************************
5670    !
5680    Lodp=Lod(I)/Conlb    ! CONVERTS CURRENT LOAD TO Lbs FOR CALC
5690    Deflc(1)=Lodp
5700    FOR J=2 TO 4
5710       Deflc(J)=Deflc(J-1)*Deflc(1)
5720    NEXT J
5730    Totcor=Corr(1)       ! PREVIOUSLY ASSIGNED AS NOTED.
5740    FOR J=1 TO 4
5750       Totcor=Totcor+Corr(J+1)*Deflc(J)
5760    NEXT J
5770    !
5780    Totcor=Totcor*Conlen    ! CONVERTS TOTAL CORRECTION FACTOR FROM (in) TO (
mm)
5790    !
5800    !
5810    RETURN      ! RETURNS TO Data_acq OR Take_data ROUTINE
```

```
5820   !
5830   !****************************************
5840   !
5850 Crack_length: ! CALCULATES CRACK LENGTH USING HUDAK (DTNSRDC PROG) [PROF. J
. JOYCE'S EQUATION]
5860   !  NOTE: THIS ROUTINE USES COD COMPLIANCE  METHOD VICE DEFLECTION COMPLIA
NCE.
5870   FOR I=1 TO 6
5880      READ Coef(I)
5890   NEXT I
5900   Compl=1/Stiff
5910   C=2*W*Beff*E*Compl/Hs/1000
5920   C=1/(SQR(C)+1)
5930   G(1)=C
5940   FOR I=2 TO 5
5950      G(I)=G(I-1)*G(1)
5960   NEXT I
5970   F=Coef(1)
5980   FOR I=1 TO 5
5990      F=F+Coef(I+1)*G(I)
6000   NEXT I
6010   Crckl=F*W
6020   RESTORE
6030   DATA 0.998265,-3.81662,-1.80596,32.31038,-44.15665,-52.67876
6040   !
6050   RETURN        ! RETURNS TO Initial_a OR Main_prog
6060   !
6070   !****************************************
6080   !
6090 Conv_data:    ! INPUTS CONVERSION DATA FOR MEASURING DEVICES
6100   PRINT CHR$(12)           ! CLEARS CRT
6110   PRINT "INPUT: LOAD RANGE, STRAIN RANGE, STROKE RANGE"
6120   PRINT "    (ENTER IN PERCENT ie. 10,20,50,100)"
6130    INPUT Lr,Cr,Sr
6140   PRINT ""
6150   PRINT "LOAD RANGE = ";Lr
6160   PRINT "STRAIN (COD) RANGE = ";Cr
6170   PRINT "STROKE (DEFLECTION) RANGE = ";Sr
6180   Lmax=20000      ! MAX LOAD RANGE IN (lbs).
6190   Cmax=.200       ! MAX COD RANGE IN (in).
6200   Smax=5.0        ! MAX STROKE RANGE IN (in).
6210   V=10            ! MAX VOLTAGE IN (volts).
6220   !
6230   ! MAXIMUM OPERATING POINTS ARE:
6240   Olmax=Lmax*Lr/100
6250   Ocmax=Cmax*Cr/100
6260   Osmax=Smax*Sr/100
6270   !
6280   ! CONVERSION CONSTANTS ARE: (ENGLISH UNITS)
6290   Sle(1)=Olmax/V
6300   Sle(2)=Ocmax/V
6310   Sle(3)=Osmax/V
6320   ! CONVERTING TO METRIC:
6330   Conlen=25.4               ! 25.4mm = 1in
6340   Conlb=4.448221615       ! 4.448221615N = 1lb      (HP PROGRAMING BOOK)
6350   !
6360   ! Sle(1,2,3) IS USED TO DENOTE CONVERSION OF VOLTAGE TO ENGLISH UNITS.
6370   Sl(1)=Sle(1)*Conlb*(-1.0)   ! COMPRESSIVE LOAD IS NEGATIVE VOTLAGE
6380   Sl(2)=Sle(2)*Conlen
6390   Sl(3)=Sle(3)*Conlen*(-1.0)    ! COMPRESSIVE STROKE SUPPLIES A NEGATIVE VOL
TAGE
```

```
6400    !
6410    PRINT ""
6420    PRINT ""
6430    PRINT "YOUR ENTRIES HAVE PRODUCED THE FOLLOWING         CONVERSION DATA:
"
6440    PRINT ""
6450    PRINT "FOR LOAD: ";S1(1);"NEWTON/VOLT  (";S1e(1);"Lbs/V)"
6460    PRINT ""
6470    PRINT "FOR COD: ";S1(2);"mm/V  (";S1e(2);"in/V)"
6480    PRINT ""
6490    PRINT "FOR DEFLECTION: ";S1(3);"mm/V  (";S1e(3);"in/V)"
6500    PRINT ""
6510    PRINT "WOULD YOU LIKE A HARD COPY?"
6520    INPUT H$
6530    IF H$="N" OR H$="NO" THEN 6630
6540    !
6550    PRINTER IS 706           ! TOGGLES PRINTER
6560    PRINT ""
6570    PRINT "       CONVERSION DATA"
6580    PRINT "FOR LOAD:";S1(1);"N/V    (";S1e(1);"Lbs/V)"
6590    PRINT "FOR COD:";S1(2);"mm/V    (";S1e(2);"in/V)"
6600    PRINT "FOR DEFLECTION:";S1(3);"mm/V   (";S1e(3);"in/V)"
6610    PRINTER IS 1             ! TOGGLES PRINTER
6620    !
6630    PRINT CHR$(12)
6640    !
6650    RETURN          ! RETURNS TO k-KEY SELECTION
6660    !
6670    !****************************************
6680    !
6690 Slope:   ! LINEAR LEAST SQUARES FIT
6700    PRINT CHR$(12)          ! CLEAR CRT
6710    ! INITIALIZE VARIABLES
6720    P2=0         ! USED AS A COUNTER
6730    Sumx=0       ! SUM OF X VALUES
6740    Sumx2=0      ! SUM OF X SQUARED VALUES
6750    Sumy=0       ! SUM OF Y VALUES
6760    Sumy2=0      ! SUM OF Y SQUARED VALUES
6770    Sumxy=0      ! SUM OF THE PRODUCT
6780    FOR I=K1 TO K3    ! K1=INDEX OF FIRST, K3=INDEX OF LAST DATA POINT USED.
6790       ! TYPE OF PLOT
6800       IF C2=1 THEN 6840          ! LOAD vs COD
6810       IF C2=2 THEN 6880          ! LOAD vs DEFL
6820       IF C2=3 THEN 6920          ! J vs DELTA_a
6830       !
6840       X=Cod(I)
6850       Y=Lod(I)
6860       GOTO 6990
6870       !
6880       X=Defl(I)
6890       Y=Lod(I)
6900       GOTO 6990
6910       !
6920       X=Delta_a(I)
6930       Y=J9(I)
6940       !
6950       ! CHECK IF DATA POINT IS WITHIN BOUNDS
6960       IF Delta_a(I)<J9(I)/(2*Fs)+.15 THEN 7050     ! CHECKS LOWER LIMIT
6970       IF Delta_a(I)>J9(I)/(2*Fs)+1.5 THEN 7050     ! CHECKS UPPER LIMIT
6980       !
6990       Sumx=Sumx+X
```

```
7000      Sumy=Sumy+Y
7010      Sumx2=Sumx2+X*X
7020      Sumy2=Sumy2+Y*Y
7030      Sumxy=Sumxy+X*Y
7040      GOTO 7060        ! GET NEXT DATA POINT
7050      P2=P2+1          ! INCREMENTS COUNTER EACH TIME A POINT IS ELIMINATED.
7060   NEXT I
7070   K3=K3-P2        ! USED TO CALCULATE NUMBER OF DATA POINTS WITHIN BOUNDS.
7080   K4=K3-K1+1          ! K4=TOTAL # DATA POINTS USED IN CALC
7090   Qa1=Sumx2-Sumx*Sumx/K4
7100   Qa2=Sumxy-Sumx*Sumy/K4
7110   Qa3=Sumy2-Sumy*Sumy/K4
7120   !
7130   M=Qa2/Qa1                 ! SLOPE
7140   !
7150   IF M<0 THEN 7430    ! IF SLOPE < 0, BAD DATA
7160   !  FROM DTNSRDC PROGRAM
7170   Q1=(K4*Sumx2-Sumx^2)/(K4*(K4-1))
7180   Q2=(K4*Sumy2-Sumy^2)/(K4*(K4-1))
7190   Q3=(K4-1)*(Q2-M*M*Q1)/(K4-2)
7200   Q4=SQR(Q3/(Q1*(K4-1)))
7210   !
7220   B=(Sumy-M*Sumx)/K4      ! INTERCEPT
7230   !
7240   Correl=M*SQR(Q1/Q2)
7250   !
7260   Qa4=SQR(ABS((Sumy2-B*Sumy-M*Sumxy)/(K4-2)))
7270   Sigmab=Qa4/SQR(ABS(Qa1))
7280   Sigmam=Sigmab*SQR(Sumx2/K4)
7290   Stiff=M                       ! STIFF = SLOPE
7300   Compl=1/M           ! COD COMPLIANCE = 1/SLOPE
7310   !
7320   ! STUDENT t TEST
7330   U4=Q4
7340   T9=1.96
7350   IF K4>120 THEN 7410             ! RETURNS
7360   T9=2.1
7370   IF K4<20 THEN 7410              ! RETURNS
7380   N9=K4-2
7390   T9=N9/(-.617109+N9*.510239)
7400   !
7410   RETURN
7420   !
7430   PRINT "POOR DATA-- SLOPE < 0"
7440   M=333333.3
7450   Correl=0
7460   !
7470   RETURN        ! RETURNS TO Initial_a, Main_prog or R_curve ROUTINE (WHICHE
VER CALLED IT)
7480   !
7490   !****************************************
7500   !
7510 Data_file:      ! ESTABLISHES DATA FILE
7520   !  THE FILE YOU CREATE CAN BE READ BY THE   "J_DATA" PROGRAM
7530   !
7540   ! NOTE: ANY CHANGES MADE TO THIS ROUTINE MAY REQUIRE SIMILAR CHANGES TO "
J_DATA" PROGRAM DUE
7550   ! TO DISK FORMATTING CONSULT HP MANUAL FOR ASSISTANCE.
7560   !
7570   PRINT CHR$(12)     ! CLAERS CRT
```

```
7580   PRINT "THIS ROUTINE WILL CREATE A DATA FILE ON DISK FOR THE TEST."
7590   PRINT ""
7600   PRINT "INSERT AN INITIALIZED DATA DISK AND ENTER FILE      NAME (SAMPLE I
D IS SUGGESTED)."
7610   INPUT Name$
7620   PRINT ""
7630   PRINT "IS THIS A NEW FILE?"
7640   INPUT Q$
7650   IF Q$="N" OR Q$="NO" THEN 7680
7660   !
7670   CREATE BDAT Name$,6,40000
7680   ASSIGN @File TO Name$
7690   !
7700   PRINT ""
7710   PRINT "FOR RECORD PURPOSES THE FOLLOWING DATA IS ALSO      RECORDED:"
7720   PRINT ""
7730   PRINT "ENTER THE DATE (MM-DAY-YEAR):"
7740   INPUT Data$(1)
7750   PRINT ""
7760   PRINT "ENTER THE TIME (HH:MM):"
7770   INPUT Data$(2)
7780   PRINT ""
7790   PRINT "ENTER THE OPERATOR'S NAME:"
7800   PRINT "     (UP TO 10 CHARACTERS)"
7810   INPUT Data$(3)
7820   PRINT ""
7830   PRINT "ENTER SPECIMEN ID:"
7840   PRINT "     (UP TO 10 CHARACTERS)"
7850   INPUT Data$(4)
7860   ! WRITE ON DISK
7870   FOR I=1 TO 4
7880      OUTPUT @File;Data$(I)[1;10]
7890   NEXT I
7900   !
7910   BEEP
7920   PRINT ""
7930   PRINT "DATA FILE HAS BEEN CREATED."
7940   !
7950   !
7960   RETURN      ! RETURNS TO k-KEY SELECTION
7970   !
7980   !****************************************
7990   !
8000 Stor_data:   ! WRITES DATA ON DISK
8010   !
8020   ! THE ITEMS STORED BY THIS ROUTINE CAN BE
8030   ! RECALLED USING THE "J_DATA" PROGRAM
8040   ! CARE MUST BE TAKEN IF ANY CHANGES ARE MADE TO THIS ROUTINE SUCH THAT SI
MILAR CHAGES ARE
8050   ! MADE TO THE "J_DATA" PROGRAM.
8060   !
8070   IF K2>0 THEN 8160          ! K2 IS UNLOADING COUNTER
8080      OUTPUT @File;A0(D2),Amin0(D2),Amax0(D2),Compl0(D2),Correl0(D2),K
8090   !
8100   PRINT ""
8110   PRINT ""
8120   PRINT "INITIAL CRACK LENGTH (a0) INFORMATION FROM         MEASUREMENT #";
D2
8130   PRINT "IS NOW IN DISK FILE ";Name$
8140   !
```

```
8150    IF K2=0 THEN 8220       ! SKIP IF THIS WAS a0 MEASUREMENT
8160       OUTPUT @File;K2,Al(K2),Delta_a(K2),K,L,Correl,Compl,Amin,Amax,Area9(K2
),J9(K2)
8170       OUTPUT @File;Mdefl(K2),Codiff,K0,K1
8180    !
8190    PRINT ""
8200    PRINT "UNLOADING INFORMATION IS NOW IN DISK FILE ";Name$
8210    !
8220    BEEP
8230    ! WAIT 3      ! ALLOWS A PAUSE SO MESSAGE IS PRESENTED ON THE CRT
8240    !
8250    !
8260    RETURN      ! RETURNS TO Initial_a OR Main_prog
8270    !
8280    !*****************************************
8290    !
8300 Take_data:  ! THIS ROUTINE IS USED TO TAKE DATA DURING THE ACTUAL TEST.
8310    !
8320    I=K                          ! INDEX
8330    OUTPUT Dvm;"AI1 VT1"         ! READS LOAD
8340    ENTER Dvm;Lod(I)
8350    Lod(I)=Lod(I)*Sl(1)
8360    !
8370    OUTPUT Dvm;"AI2 VT1"      ! READS COD
8380    ENTER Dvm;Cod(I)
8390    Cod(I)=Cod(I)*Sl(2)
8400    !
8410    OUTPUT Dvm;"AI3 VT1"      ! READS DEFLECTION
8420    ENTER Dvm;Defl(I)
8430    Defl(I)=Defl(I)*Sl(3)
8440    !
8450    GOSUB Correct_defl        ! DETERMINE CORRECTION FACTOR FOR SYSTEM COMPLIA
NCE
8460    !
8470    Defl(I)=Defl(I)-Totcor
8480    !
8490    !   PLOT THE DATA POINT
8500    VIEWPORT 13,100*RATIO,10,90
8510    WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
8520    IF C2=2 THEN 8550
8530       PLOT Cod(I),Lod(I)
8540    GOTO 8560
8550       PLOT Defl(I),Lod(I)
8560    !
8570    !
8580    RETURN      ! RETURNS TO Main_prog
8590    !
8600    !*****************************************
8610    !
8620 J_calc:  ! CALCULATES J WITH CRACK GROWTH CORRECTION ERNST MODEL (USED BY D
TNSRDC)
8630    !
8640    E5=2
8650    !  CALCULATE J FOR FIRST (1st) UNLOADING
8660    IF K2>1 THEN 8690
8670    J6=J7+E5/(W-Al(K2))*Area9(K2)/Bmin
8680    GOTO 8730
8690    J6=J7+E5/(W-Al(K2))*(Area9(K2)-Area9(K2-1))/Bmin
8700    ! IF DELTA_a < 0.254mm DO NOT USE CRACK GROWTH CORRECTION
8710    IF Delta_a(K2)<.254 THEN 8730
```

```
8720   J6=J6*(1-1/(W-A1(K2))*(A1(K2)-A1(K2-1)))   ! CORRECTS FOR CRACK GROWTH (A
STM E813-81)
8730   J7=J6
8740   !
8750   J9(K2)=J6          ! STORES CURRENT J VALUE IN  J9 ARRAY.
8760   !
8770   RETURN       ! RETURNS TO Main_prog
8780   !
8790   !****************************************
8800   !
8810 Main_prog:  ! THIS IS THE MAIN PROGRAM FOR   THE J-INTEGRAL TEST.
8820   !
8830   PRINT CHR$(12)       ! CLEARS CRT
8840   PRINT ""
8850   PRINT "ENSURE YOU HAVE COMPLETED THE FOLLOWING ITEMS         BEFORE PROCE
EDING:"
8860   PRINT "    1. ENTERED SPECIMEN DATA."
8870   PRINT "    2. ENTERED CONVERSION DATA."
8880   PRINT "    3. SET UP INTEACTIVE PLOTTER."
8890   PRINT "    4. OBTAINED INITIAL CRACK LENGTH."
8900   PRINT ""
8910   PRINT " ARE YOU READY?"
8920   INPUT H$
8930   IF H$="NO" OR H$="N" THEN 10530  ! RETURNS TO WAIT FOR k-KEY SELECTION
8940   PRINT ""
8950   PRINT ""
8960   PRINT "WHAT IS YOUR EXPECTED MAXIMUM LOAD IN NEWTONS?"
8970   INPUT Pmax
8980   Lod5=.1*Pmax      ! USED TO SIGNAL TURN AROUND FROM UNLOADING
8990   !
9000   PRINT "THE TEST SHOULD START WITH NEAR ZERO (0) LOAD WITH THE MTS IN 'STR
OKE' CONTROL."
9010   PRINT ""
9020   PRINT "ENSURE THIS IS DONE."
9030   PRINT ""
9040   PRINT "WHEN YOU ARE READY PRESS 'ENTER' OR 'CONTINUE' KEY AND START THE M
TS MACHINE."
9050   INPUT H$
9060   PRINT CHR$(12)       ! CLEARS CRT
9070   !
9080   !
9090   !  INITIALIZE VARIABLES
9100   Area=0     ! AREA UNDER LOAD vs DEFLECTION CURVE   DTNSRDC (I8)
9110   Area9(1)=0 ! AREA BENEATH SPECIFIC LOD vs DEFL (DTNSRDC I9(K2))
9120   K=K        ! CURRENT INDEX (AFTER OBTAINING INITIAL CRACK LENGTH)
9130   I=K        ! INDEX OF FIRST TEST DATA POINT
9140   K0=K       ! WHERE TEST DATA STARTS
9150   K1=0       ! LOWER INDEX FOR SLOPE CALC
9160   K2=0       ! A COUNTER       "     (K2)  NUMBER OF UNLOADINGS
9170   K3=0       ! UPPER INDEX FOR SLOPE CALC
9180   L=1        ! A COUNTER   DTNSRDC (L)      "   "  DATA POINTS TAKEN DURING
UNLOADING
9190   Lod1=0     ! TEMP LOAD       "     (P1)  USED IN AREA CALC
9200   Lod2=0     ! TEMP LOAD       "     (P2)   "   "   "   "
9210   Lod5=.1*Pmax  !              "     (P5)  USED FOR TURN AROUND SIGNAL
9220   Lod9=0     ! MAX LOAD        "     (P9)
9230   Cod1=0     ! TEMP COD        "     (D1)
9240   Cod2=0     ! TEMP COD        "     (D2)
9250   Cod4=0     ! TEMP COD        "     (C4)
```

```
9260    Cod9=0      ! MAX COD          "      (D9)
9270    Codiff=0    ! COD DIFFERENCE "      (D3)
9280    Defl1=0     ! TEMP DEFL        "      (D4)  USED IN AREA CALC
9290    Defl2=0     ! TEMP DEFL        "      (D5)   "    "    "    "
9300    J6=0        ! JI FROM CURRENT UNLOAD
9310    J7=0        ! JI FROM PREVIOUS UNLOAD DTNSDRC (J7)
9320    I1=0        ! FLAG (0=LOADING, 1=UNLOADING)
9330    F1=0        ! FLAG (F1=999 ENDS TEST)
9340    !
9350    !
9360    PRINT ""
9370    !
9380    IF F1=999 THEN GOSUB End_test
9390    !
9400    GOSUB Take_data
9410    Defl6=Defl(I)
9420    Lod7=Lod(I)
9430    Lod2=Lod(I)
9440    Defl2=Defl(I)
9450    Cod2=Cod(I)
9460    !
9470    ! TEST CONDITIONS OF DATA POINT JUST TAKEN
9480    IF (K-K0)<20 THEN 10430   ! CALC AREA & TAKE MORE DATA
9490    Codiff=Cod2-Cod1
9500    IF Codiff<-3.0E-4 THEN 9540   ! IF CODIFF IS (-) CHECK IF LOADING OR UNLO
ADING
9510    IF I1=0 THEN 10430    ! IF LOADING CALC AREA & TAKE MORE DATA
9520    IF Cod2>Cod9 THEN 9600    ! IF TRUE CHECK IF GOOD UNLOADING
9530    GOTO 10340            ! DISREGARD UPPER 2% OF UNLOADING CURVE
9540    IF I1<>0 THEN 10340   ! IF UNLOADING CHECK  IF ON UPPER 2% OF CURVE
9550    Lod9=Lod2             ! IF LOADING MAKE CURRENT LOAD = MAXIMUM LOAD
9560    Cod9=Cod2             ! MAKE CURRENT COD = MAX COD
9570    Defl9=Defl2           ! MAKE CURRENT DEFL = MAX DEFL
9580    I1=1            ! MUST BE UNLOADING
9590    GOTO 10340      ! TEST IF UPPER 2% OF UNLOADING
9600    IF L<5 THEN 10290 ! BAD UNLOADING. SET I1=1
9610    K1=K-L          ! SETS LOWER INDEX FOR SLOPE CALCULATION.
9620    K3=K1+L         ! SETS UPPER INDEX FOR SLOPE CALCULATION.
9630    PENUP
9640    !
9650    K2=K2+1             ! INCREMENT UNLOADING COUNTER
9660    !
9670    GOSUB Slope         ! IF GOOD UNLOADING
9680    Stiff2=Stiff
9690    GOSUB Crack_length    ! CALC CRACK LENGTH
9700    A1(K2)=Crckl          ! CURRENT CRACK LENGTH
9710    Delta_a(K2)=A1(K2)-A1       ! DETERMINE CRACK GROWTH
9720    !
9730    ! NOTE: A1 = INITIAL CRACK LENGTH: ASSIGNED IN Initial_a ROUTINE.
9740    !
9750    Crckl4=Crckl
9760    PRINT "        ----  UNLOADING #";K2;" ---"
9770    ! PRINT ""
9780    PRINT "CRACK LENGTH =";A1(K2);"mm"
9790    PRINT "DELTA_a =";Delta_a(K2);"mm"
9800    PRINT "TOTAL # DATA POINTS = ";K
9810    PRINT "# DATA POINTS THIS UNLOADING =";L
9820    PRINT "CORRELATION =";Correl
9830    PRINT "COD COMPLIANCE =";Compl;"mm/N"
```

```
9840   !
9850   Area9(K2)=Area
9860   !
9870   ! CALCULATE 95% CONFIDENCE INTERVAL
9880   Stiff=Stiff+T9*U4
9890   GOSUB Crack_length
9900   Amax=Crckl
9910   Stiff=Stiff-2*T9*U4
9920   GOSUB Crack_length
9930   Stiff=Stiff2
9940   Amin=Crckl
9950   PRINT ""
9960   PRINT "95% CONFIDENCE INTERVAL ON CRACK LENGTH FROM ";Amin;"TO";Amax
9970   !
9980   GOSUB J_calc  ! CALC J (USES J-ERNST MODEL)
9990   !
10000  Mdefl(K2)=Defl(K)     ! MAX DEFLECTION
10010  !
10020  ! PRINT ""
10030  PRINT "AREA =";Area9(K2);"N*mm"
10040  PRINT "J =";J9(K2);"KJ/m^2"
10050  PRINT "LOAD LINE DEFLECTION =";Mdefl(K2);"mm"
10060  PRINT "CHANGE IN COD =";Codiff;"mm"
10070  PRINT "K0=";K0;"  K1=";K1
10080  !
10090  !
10100  GOSUB Prt_results             ! PRINTS RESULTS ON PRINTER
10110  !
10120  ! DATA POINTS CAN BE PRESENTED FOR REVIEW BY SIMPLY REMOVING THE REMARK C
HARACTER (!).
10130  PRINT ""
10140  ! PRINT " PT #     LOAD(N)       DEFLECTION(mm)    COD(mm)"
10150  ! FOR I=(K1-1) TO K
10160     ! PRINT USING 9170;I,Lod(I),Defl(I),Cod(I)
10170     ! IMAGE 4D,4X,5D.D,6X,DD.6D,7X,DD.6D
10180  ! NEXT I
10190  ! WAIT 5         ! PAUSE TO ALLOW VIEWING
10200  !
10210  !
10220  GOSUB Stor_data        ! STORES INFORMATION ON DISK
10230  !
10240  !
10250  IF Crckl4-A1>0 THEN 10290
10260  PRINT ""
10270  PRINT "    NO  CRACK  EXTENSION  THIS  POINT."
10280  PRINT ""
10290  I1=0
10300  L=1
10310  ! IF L=1 THEN K1=K   ! SETS LOWER INDEX FOR  SLOPE CALCULATION AT CURRENT
 K
10320  GOTO 10360
10330  IF Cod2<Cod1 THEN 10440   !  GET MORE DATA
10340  IF Lod2>.98*Lod9 THEN 10440    ! DISREGARD UPPER 2% OF UNLOADING & GET MO
RE DATA
10350  L=L+1          ! INCREMENT DATA POINT COUNTER
10360  IF Lod2>Lod9-Lod5 THEN 10440       ! IF TRUE GET MORE DATA
10370  BEEP          ! SENDS OUT BEEP
10380  BEEP          ! AS TURN AROUND
10390  BEEP          ! SIGNAL TO BEGIN RELOADING
10400  GOTO 10440  ! RESUME TAKING AND TEST DATA
10410  !
10420  !   CALCULATE AREA UNDER LOAD vs DEFLECTION CURVE
```

```
10430  Area=Area+(Defl2-Defl1)*(Lod2+Lod1)/2
10440  Lod1=Lod2
10450  K=K+1         ! INCREMENT TOTAL # DATA POINTS COUNTER
10460  Cod1=Cod2
10470  Defl1=Defl2
10480  !
10490  GOTO 9380      ! LOOP BACK CHECK IF TEST IS
10500  !                OVER, IF NOT TAKE MORE DATA.
10510  !
10520  !
10530  RETURN       ! NEVER REACH THIS BUT ROUTINE WOULD NOT BE VALID WITHOUT IT
10540  !
10550  !*********************************************
10560 Prt_results:       ! PRINTS TEST INFORMATION WHILE PROGRAM IS RUNNING
10570  PRINTER IS 706    ! TOGGLES PRINTER
10580  PRINT ""
10590  PRINT "       ----  UNLOADING #";K2;" ----"
10600  PRINT ""
10610  PRINT "CRACK LENGTH =";Al(K2);"mm     DELTA _a =";Delta_a(K2);"mm"
10620  PRINT "95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM";Amin;" TO";Amax
10630  PRINT ""
10640  PRINT "TOTAL # DATA POINTS =";K;"    # DATA POINTS THIS UNLOADING =";L
10650  PRINT "CORRELATION =";Correl
10660  PRINT "COD COMPLIANCE =";Compl;"mm/N"
10670  PRINT ""
10680  PRINT "AREA =";Area9(K2);"N*mm"
10690  PRINT "J =";J9(K2);"KJ/m^2"
10700  PRINT "MAX LOAD LINE DEFLECTION =";Mdefl(K2);"mm"
10710  PRINT "CHANGE IN COD =";Codiff;"mm"
10720  !
10730  PRINT ""
10740  PRINTER IS 1      ! TOGGLES PRINTER TO CRT
10750  !
10760  RETURN            ! RETURNS TO Main_prog
10770  !
10780  !*********************************************
10790  !
10800 Stor_arrays:  ! STORES ARRAYS (Lod,Defl,Cod) ON DISK
10810  !
10820  ! THE ARRRAYS CAN BE RECALLED LATER USING
10830  ! THE "J_DATA" PROGRAM.
10840  !
10850     OUTPUT @File;Lod(*),END
10860     OUTPUT @File;Defl(*),END
10870     OUTPUT @File;Cod(*),END
10880  !
10890  BEEP
10900  !
10910  !
10920  RETURN       ! RETURNS TO End_test
10930  !
10940  !*********************************************
10950  !
10960 End_test:     ! ENDS TEST
10970  !
10980  PRINT CHR$(12)
10990  !
11000  !
11010  GOSUB Stor_arrays
11020  !
```

```
11030  PRINT "DATA HAS BEEN STORED ON DISK IN FILE ";Name$
11040  !
11050  GOSUB R_curve
11060  !
11070  PRINT ""
11080  PRINT "  TEST IS OVER!!"
11090  PRINT ""
11100  PRINT ""
11110  PRINT ""
11120  PRINT ""
11130  PRINT ""
11140  PRINT "        TEST IS OVER!"
11150  PRINT ""
11160  PRINT ""
11170  PRINT ""
11180  PRINT ""
11190  PRINT ""
11200  PRINT "              TEST IS OVER!"
11210  !
11220  !
11230  GOTO 12590       ! GO TO END STATEMENT
11240  !
11250  RETURN   ! NEVER REACH THIS POINT BUT ROUTINE WOULD NOT BE VALID WITHOUT
IT
11260  !
11270  !****************************************
11280  !
11290 R_curve:  ! J vs DELTA_a DATA  IS PRESENTED FOR PLOTTING
11300  !
11310  PRINT ""
11320  !
11330  ! ALL (*) STATEMENTS WILL ALLOW DIRECT INPUT OF Delta_a(I) vs J9(I) DATA
11340  ! YOU MUST REMOVE [!(*)] FROM BEGINNING OF EACH LINE TO ACTIVATE
11350  !(*) PRINT "INPUT THE # OF UNLOADINGS"
11360  !(*) INPUT K2
11370  !(*) PRINT "ENTER DELTA_A(I),J9(I)"
11380  PRINT "UNLOADING #    DELTA_a(mm)      J(kJ/m^2)"
11390  FOR I=1 TO K2
11400     !(*) INPUT Delta_a(I),J9(I)
11410     PRINT USING 11420;I,Delta_a(I),J9(I)
11420     IMAGE 6X,3D,4X,DD.6D,5X,6D.D
11430  NEXT I
11440  PRINT ""
11450  PRINT "DO YOU WANT A HARD COPY?"
11460  INPUT H$
11470  IF H$="N" OR H$="NO" THEN 11680
11480  !
11490  PRINTER IS 706         ! TOGGLES TO THERMAL PRINTER
11500  PRINT "UNLOADING #     DELTA_a(mm)     J(kJ/m^2)"
11510  FOR I=1 TO K2
11520     PRINT USING 11420;I,Delta_a(I),J9(I)
11530  NEXT I
11540  PRINTER IS 1     ! RETURNS TO CRT AS PRINTER
11550  !
11560  !(*) PRINT "ARE ALL OKAY?"
11570  !(*) INPUT G$
11580  !(*) IF G$="Y" THEN 11582
11590  !(*) PRINT "INPUT I (INDEX) OF BAD #"
11600  !(*) INPUT L1
11610  !(*) PRINT "INPUT VALUES OF DELTA_A(I) AND J9(I)"
```

```
11620  !(*) INPUT Delta_a(L1),J9(L1)
11630  !(*) PRINT "ARE YOU OK"
11640  !(*) INPUT Eee$
11650  !(*) IF Eee$="N" THEN GOTO 11574
11660  ! END OF (*) CHANGES REQUIRED FOR DIRECT INPUT OF DELTA_A(I) vs J9(I) DAT
A
11670  !
11680  PRINT ""
11690  PRINT "DO YOU WANT A PLOT OF J vs DELTA_a?"
11700  INPUT R$
11710  IF R$="N" OR R$="NO" THEN 12550
11720  PRINT ""
11730  PRINT "WHEN THE PLOTTER IS READY (NEW GRAPH PAPER INSTALLED) PRESS 'ENTER
' OR 'CONTINUE' KEY"
11740  INPUT C$
11750  !
11760  GOSUB Setup_plotter
11770  !
11780  ! PLOT THE DATA THE DATA POINTS
11790  VIEWPORT 13,100*RATIO,10,90
11800  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
11810  FOR I=1 TO K2
11820     X=Delta_a(I)
11830     Y=J9(I)
11840     MOVE X-X3*.005,Y+Y3*.005       ! DRAWS A
11850     DRAW X+X3*.005,Y-Y3*.005       ! SMALL X
11860     MOVE X+X3*.005,Y+Y3*.005       ! FOR DATA
11870     DRAW X-X3*.005,Y-Y3*.005       ! POINT
11880  NEXT I
11890  !
11900  ! PLOT THE BLUNTING LINE
11910  VIEWPORT 13,100*RATIO,10,90
11920  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
11930     Bly=Y2(C2)-Y3/8        ! TAKES LINE TO 7/8 OF Ymax
11940     Blx=Bly/(2*Fs)*1000       ! DELTA_a = J/2*Fs
11950       MOVE 0,0
11960       DRAW Blx,Bly
11970       !
11980       Blminx=Blx+.15     ! DRAWS LOWER BOUNDS
11990       MOVE .15,0
12000       LINE TYPE 4
12010       DRAW Blminx,Bly
12020       !
12030       Blmaxx=Blx+1.5     ! DRAWS UPPER BOUNDS
12040       MOVE 1.5,0
12050       LINE TYPE 4
12060       DRAW Blmaxx,Bly
12070       PENUP
12080       !
12090  K1=1                    ! LOWER INDEX FOR LEAST SQUARES FIT
12100  K3=K2                   ! UPPER INDEX
12110  GOSUB Slope
12120  !
12130  ! PLOT THE LINE OBTAINED
12140  VIEWPORT 13,100*RATIO,10,90
12150  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
12160     Xplt=X2(C2)-X3/8     ! TAKES LINE TO 7/8 OF Xmax
12170     Yplt=Xplt*M+B
12180     MOVE 0,B
12190     LINE TYPE 6
```

```
12200     DRAW Xplt,Yplt
12210     PENUP
12220  PRINT ""
12230  PRINT "ONLY DATA WITHIN BOUNDS IS USED"
12240  PRINT "FOR LEAST SQUARES FIT."
12250  PRINT ""
12260  PRINT "SLOPE=";M;" INTERCEPT=";B
12270  PRINT "CORREL=";Correl
12280  PRINT "NUMBER OF DATA POINTS USED:";K4
12290  !
12300  PRINTER IS 706         ! TOGGLES PRINTER
12310  PRINT ""
12320  PRINT ""
12330  PRINT "DATA FROM J vs DELTA_a PLOT"
12340  PRINT ""
12350  PRINT "SLOPE =";M;"    Y-INTERCEPT =";B
12360  PRINT "CORRELATION =";Correl;"  FROM";K4;" DATA POINTS."
12370  PRINTER IS 1           ! TOGGLES PRINTER
12380  !
12390  ! FIND THE INTERSECTION, HENCE J(1c).
12400  ! SOLVE BOTH EQUATIONS SIMULTANEOUSLY
12410  ! J = M*(DELTA_a)+B = (DELTA_a)*(2*Fs)  HENCE:
12420  J1c=(B/M)/(1/M-(1000/(2*Fs)))
12430  PRINT ""
12440  PRINT "      J1c =";J1c
12450  PRINTER IS 706          ! TOGGLES PRINTER
12460  PRINT ""
12470  PRINT "       J1c =":J1c
12480  PRINT ""
12490  PRINT ""
12500  PRINT " TEST IS OVER!"
12510  PRINTER IS 1            ! TOGGLES PRINTER
12520  !
12530  ! GOTO 12100       ! GO TO END STATEMENT
12540  !
12550  RETURN        ! RETURNS TO End_test ROUTINE
12560  !
12570  !****************************************
12580  !
12590 END                 ! END OF TEST AND PROGRAM
12600  !
12610  !****************************************
12620  !
12630 SUB Stop_test            ! STOPS TEST
12640  !            k9-KEY ACTS AS PROGRAM INTERRUPT
12650  ! k9-KEY IS NOT LABELED, BUT IS ASSIGNED A HIGHER PRIORITY TI INTERRUPT P
ROGRAM
12660  !
12670  COM /J_intgl/ F1
12680  F1=999                 ! SETS STOP FLAG
12690  !
12700 SUBEND
12710  !****************************************
```

APPENDIX F

J_DATA LISTING

```
10   !             J_DATA PROGRAM
20   ! THIS PROGRAM WILL ALLOW YOU TO READ A DATA
30   ! FILE CREATED BY "J_INTGL".  YOU MUST KNOW
40   ! HOW MANY UNLOADINGS WERE RECORDED DURING
50   ! THE TEST TO USE THIS PROGRAM.
60   !
70   ! PROGRAM WAS WRITTEN BY:
80   !    LCDR W.K. TRITCHLER
90   ! VERSION 1.0     DATE 11/83
100  !
110  !
120  !
130  DIM Data$(1:4)[10]
140  DIM Lod(8000),Defl(8000),Cod(8000)
150  DIM Al(100),Area9(100),Delta_a(100)
160  DIM Mdefl(100),J9(100)
170  !
180  PRINT CHR$(12)     ! CLEARS CRT
190  !
200  DUMP DEVICE IS 706
210  PRINT "WHAT DATA FILE DO YOU WISH TO READ?"
220  INPUT Name$
230  ASSIGN @File TO Name$
240  FOR I=1 TO 4
250    ENTER @File;Data$(I)[1:10]
260  NEXT I
270  PRINT ""
280  PRINT "J-INTEGRAL TEST OF ";Data$(4);"BY: ";Data$(3)
290  PRINT ""
300  PRINT "DATE: ";Data$(1);"      TIME: ";Data$(2)
310     ENTER @File;Crckl,Amin,Amax,Compl,Correl,K
320  PRINT ""
330  PRINT ""
340  PRINT ""
350  PRINT "a0=";Crckl,"WITH 95% CONDIFENCE INTERVAL  FROM";Amin;"   TO";Amax
360  PRINT ""
370  PRINT "FROM COMPLIANCE = ";Compl
380  PRINT ""
390  PRINT "CORRELATION=";Correl;"FROM";K;"DATA POINTS"
400  PRINT ""
410  PRINT "DO YOU WANT A HARD COPY OF THIS INFORMATION?"
420  INPUT G$
430  IF G$="N" OR G$="NO" THEN 450
440  DUMP ALPHA
450  PRINT ""
460  PRINT "INPUT THE NUMBER OF UNLOADINGS THAT WERE RECORDED DURING THE TEST."
470  INPUT C1           ! WILL BE USED AS COUNTER
480  FOR I=1 TO C1
490     ENTER @File;K2,Al(K2),Delta_a(K2),K,L,Correl,Compl,Amin,Amax,Area9(K2),
J9(K2)
500     ENTER @File;Mdefl(K2),Codiff,K0,K1
510     GOSUB Prt_results     ! DISPLAYS INFO
520     PRINT ""
530     PRINT "DO YOU WANT A HARD COPY?"
540     INPUT Q$
550     IF Q$="N" OR Q$="NO" THEN 580
560     PRINTER IS 706
570     GOSUB Prt_results    ! WILL NOW PRINT INFO
580  NEXT I
590  PRINT "DO YOU WANT A LISTING OF THE DATA POINTS?"
```

```
600   INPUT E$
610   IF E$="N" OR E$="NO" THEN 830
620   PRINT ""
630   PRINT "PT #    LOAD (N)     DEFLECTION (mm)    COD (mm)"
640   ENTER @File;Lod(*),Defl(*),Cod(*)
650   FOR I=1 TO K
660      PRINT USING 670;I,Lod(I),Defl(I),Cod(I)
670      IMAGE X,4D,3X,5D.D,8X,D.6D,8X,D.6D
680   NEXT I
690   PRINT ""
700   PRINT "DO YOU WANT A HARD COPY?"
710   INPUT H$
720   IF H$="N" OR H$="NO" THEN 830
730   PRINTER IS 706
740   PRINT "DATA FROM a0 FOR:";Data$(4);"BY: ";Data$(3)
750   PRINT ""
760   PRINT "TESTED ON: ";Data$(1);"TIME: ";Data$(2)
770   PRINT ""
780   PRINT "PT #    LOAD (N)     DEFLECTION (mm)    COD (mm)"
790   FOR I=1 TO K
800      PRINT USING 670;I,Lod(I),Defl(I),Cod(I)
810   NEXT I
820   PRINTER IS 1
830   PRINT CHR$(12)          ! CLEARS CRT
840   PRINT "DO YOU WISH TO PLOT ANY DATA?"
850   INPUT P$
860   IF E$="Y" OR E$="YES" THEN 880  ! OTHERWISE MUST NOW READ DATA POINTS OFF
DISKETTE
870   ENTER @File;Lod(*),Defl(*),Cod(*)
880   IF P$="Y" OR P$="YES" THEN GOSUB Setup_plotter
890   PRINT "DO YOU WANT ANOTHER PLOT?"
900   INPUT A$
910   IF A$="Y" OR A$="YES" THEN GOSUB Setup_plotter
920   PRINT "DO YOU WANT ANOTHER PLOT?"
930   INPUT F$
940   IF F$="Y" OR F$="YES" THEN GOSUB Setup_plotter
950   PRINT "    PROGRAM IS OVER!!!"
960   PRINT ""
970   PRINT ""
980   PRINT ""
990   PRINT ""
1000  PRINT ""
1010  PRINT "             PROGRAM IS OVER!"
1020  PRINT ""
1030  PRINT ""
1040  PRINT ""
1050  PRINT ""
1060  PRINT ""
1070  PRINT "                      PROGRAM IS OVER!"
1080  !
1090  GOTO 1290
1100  !
1110  !****************************************
1120  !
1130 Prt_results:   ! DISPLAYS OR PRINTS UNLOADING INFORMATION
1140  PRINT ""
1150  PRINT "FROM UNLOADING #";K2;"RECORDED";L;"DATA POINTS"
1160  PRINT "COD COMPLIANCE =";Compl;"mm/N   CORRELATION =";Correl
1170  PRINT "CRACK LENGTH =";Ai(K2);"mm   DELTA_A =";Delta_a(K2);"mm"
1180  PRINT "95% CONFIDENCE INTERVAL FROM";Amin;"mm TO";Amax;"mm"
```

```
1190  PRINT "AREA =";Area9(K2);"N*mm    J =";J9(K2);"KPa*m"
1200  PRINT "DATA POINT INDEXES FROM";K1;"TO";K;" WERE USED."
1210  PRINT ""
1220  PRINTER IS 1
1230  !
1240  RETURN
1250  !
1260  !****************************************
1270  !
1280 Setup_plotter:     ! SET UP PLOTTER
1290  ! YOU CAN CHOOSE BETWEEN THREE DIFFERENT PLOTS
1300  PRINT CHR$(12)     ! CLEARS CRT
1310  DIM T$[80],X$[80],Y$[80]
1320  GCLEAR
1330  GINIT
1340  GRAPHICS ON
1350  PLOTTER IS 3,"INTERNAL"    ! PLOTS ON CRT
1360  PRINT "TYPE OF PLOT:"
1370  PRINT "     1.  LOAD vs COD"
1380  PRINT "     2.  LOAD vs DEFLECTION"
1390  PRINT "     3.  J vs CRACK EXTENSION"
1400  PRINT "ENTER THE # OF THE  PLOT YOU DESIRE"
1410  INPUT C2
1420  PRINT ""
1430  PRINT ""
1440  IF C2=1 THEN 1470
1450  IF C2=2 THEN 1520
1460  IF C2=3 THEN 1570
1470  T$="PLOT of LOAD vs COD for "&Data$(4)
1480  PRINT T$
1490  X$="COD (mm)"
1500  Y$="LOAD (N)"
1510  GOTO 1610
1520  T$="PLOT of LOAD vs DEFLECTION for "&Data$(4)
1530  PRINT T$
1540  X$="DEFLECTION (mm)"
1550  Y$="LOAD (N)"
1560  GOTO 1610
1570  T$="PLOT OF J vs CRACK EXTENSION for "&Data$(4)
1580  PRINT T$
1590  X$="DELTA_a (mm)"
1600  Y$="J  (kJ/m^2)"
1610  PRINT ""
1620  PRINT "USING METRIC UNITS (mm,N,kJ/m^2,etc.):"
1630  PRINT "ENTER THE  Xmin,Xmax,Ymin,Ymax"
1640  INPUT X1(C2),X2(C2),Y1(C2),Y2(C2)
1650  X3=X2(C2)-X1(C2)
1660  Y3=Y2(C2)-Y1(C2)
1670  VIEWPORT 13,100*RATIO,10,90
1680  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
1690  PRINT ""
1700  PRINT "INPUT DELTA_X AND DELTA_Y LABEL INTERVAL"
1710  PRINT "FOR THE TWO AXES:"
1720  INPUT X4,Y4
1730  PRINT ""
1740  PRINT "DO YOU WISH TO HAVE A GRID OVERLAY?"
1750  INPUT G$
1760  IF G$="N" OR G$="NO" THEN 1800
1770  PRINT ""
1780  PRINT "INPUT GRID LINES PER DELTA LABEL:"
```

```
1790  INPUT B0
1800  PRINT "PRESS 'ENTER' OR 'CONTINUE' KEY TO PLOT"
1810  INPUT H$            ! DUMMY VARIABLE
1820  PRINT CHR$(12)      ! CLEARS CRT
1830  IF G$="N" OR G$="NO" THEN 1970
1840  FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
1850     MOVE I,Y1(C2)
1860     DRAW I,Y2(C2)
1870  NEXT I
1880  FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
1890     MOVE X1(C2),I
1900     DRAW X2(C2),I
1910  NEXT I
1920  GOTO 1970
1930  IF G$="Y" OR G$="YES" THEN 1970
1940  MOVE X2(C2),Y1(C2)
1950  DRAW X2(C2),Y2(C2)
1960  DRAW X1(C2),Y2(C2)
1970  CLIP ON
1980  AXES X4,Y4,X1(C2),Y1(C2)
1990  CLIP OFF
2000  VIEWPORT 13,100*RATIO,5,90
2010  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2020  LORG 4
2030  CSIZE 3,.6
2040  FOR X=X1(C2) TO X2(C2) STEP X4
2050     CLIP OFF
2060     MOVE X,Y1(C2)
2070     LABEL USING "K";X        ! PLOTS X-DIGITS
2080  NEXT X
2090  VIEWPORT 4,100*RATIO,10,90
2100  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2110  LORG 2
2120  FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2130     CLIP OFF
2140     MOVE X1(C2),Y
2150     LABEL USING "K";Y
2160  NEXT Y
2170  VIEWPORT 0,100*RATIO,0,100
2180  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2190  CSIZE 5
2200  LORG 6            ! PLOTS TITLE
2210     MOVE X2(C2)/2,Y2(C2)
2220     LABEL T$
2230  DEG
2240  LDIR 90
2250  CSIZE 4,.7
2260     MOVE X1(C2),Y2(C2)/2
2270     LABEL Y$       ! PLOTS Y-AXIS LABEL
2280  LORG 4
2290  LDIR 0
2300     MOVE X2(C2)/2,Y1(C2)
2310     LABEL X$       ! PLOTS X-AXIS LABEL
2320  !
2330  PRINT ""
2340  PRINT ""
2350  PRINT ""
2360  PRINT ""
2370  PRINT "        IS THE PLOT (AXES AND LABELS) OK?"
2380  PRINT ""
```

```
2390  PRINT "            NOTE:  IF YOU ANSWER YES OR Y"
2400  PRINT "                   PLOT WILL BE SENT TO"
2410  PRINT "                   EXTERNAL PLOTTER"
2420  INPUT F$
2430  IF F$="N" OR F$="NO" THEN GOSUB Setup_plotter  ! REDO PLOTTER SETUP
2440  !
2450  GCLEAR       ! CLEARS PLOT FROM CRT
2460  !
2470  GOSUB Ext_plotter
2480  !
2490  PENUP
2500  MOVE 0,0
2510  !
2520  GOSUB Plot_data
2530  !
2540  RETURN
2550  !
2560  !****************************************
2570  !
2580 Ext_plotter:    ! DUMPS PLOTTER SETUP ON EXTERNAL HP-7225B PLOTTER
2590  PLOTTER IS 705,"HPGL"
2600  VIEWPORT 13,100*RATIO,10,90
2610  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2620  IF G$="N" OR G$="NO" THEN 2730
2630  FOR I=X4/B0+X1(C2) TO X2(C2) STEP X4/B0
2640     MOVE I,Y1(C2)
2650     DRAW I,Y2(C2)
2660  NEXT I
2670  FOR I=Y4/B0+Y1(C2) TO Y2(C2) STEP Y4/B0
2680     MOVE X1(C2),I
2690     DRAW X2(C2),I
2700  NEXT I
2710  GOTO 2760
2720  IF G$="Y" OR G$="YES" THEN 2760
2730  MOVE X2(C2),Y1(C2)
2740  DRAW X2(C2),Y2(C2)
2750  DRAW X1(C2),Y2(C2)
2760  CLIP ON
2770  AXES X4,Y4,X1(C2),Y1(C2)
2780  CLIP OFF
2790  VIEWPORT 13,100*RATIO,5,90
2800  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2810  LORG 4
2820  CSIZE 3,.6
2830  FOR X=X1(C2) TO X2(C2) STEP X4
2840     CLIP OFF
2850     MOVE X,Y1(C2)
2860     LABEL USING "K";X
2870  NEXT X
2880  VIEWPORT 4,100*RATIO,10,90
2890  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2900  LORG 2
2910  FOR Y=Y1(C2) TO Y2(C2) STEP Y4
2920     CLIP OFF
2930     MOVE X1(C2),Y
2940     LABEL USING "K";Y
2950  NEXT Y
2960  VIEWPORT 0,100*RATIO,0,100
2970  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
2980  LORG 2
```

```
2990  CSIZE 5
3000  LORG 6
3010     MOVE X2(C2)/2,Y2(C2)
3020     LABEL T$
3030  DEG
3040  LDIR 90
3050  CSIZE 4,.7
3060     MOVE X1(C2),Y2(C2)/2
3070     LABEL Y$
3080  LORG 4
3090  LDIR 0
3100     MOVE X2(C2)/2,Y1(C2)
3110     LABEL X$
3120  !
3130  PENUP
3140  MOVE 0,0
3150  !
3160  RETURN
3170  !
3180  !****************************************
3190  !
3200 Plot_data:        ! PLOTS TO DATA SELECTED
3210  !
3220  VIEWPORT 13,100*RATIO,10,90
3230  WINDOW X1(C2),X2(C2),Y1(C2),Y2(C2)
3240  !
3250  IF C2=1 THEN 3290
3260  IF C2=2 THEN 3340
3270  IF C2=3 THEN 3390
3280  !
3290  FOR I=1 TO K
3300     PLOT Cod(I),Lod(I)
3310  NEXT I
3320  GOTO 3430
3330  !
3340  FOR I=1 TO K
3350     PLOT Defl(I),Lod(I)
3360  NEXT I
3370  GOTO 3430
3380  !
3390  FOR I=1 TO C1
3400     PLOT Delta_a(K2),J(K2)
3410  NEXT I
3420  !
3430  PENUP
3440  BEEP
3450  RETURN        ! RETURNS TO SETUP_PLOTTER
3460  !
3470  !****************************************
3480  !
3490  END
```

APPENDIX G

PRECRACK OUTPUT

```
USING ENGLISH UNITS (in.lbs.psi) THE FOLLOWING INFORMATION
HAS BEEN ENTERED FOR: HY80-5B

WIDTH = .9469          NOTCH LENGTH = .444
Bmax = .496         Bmin = .394
HALF SPAN = 1.894  POISSON'S RATIO = .3
YIELD STRENGTH = 86600  ULTIMATE TS = 100000
ELASTIC MODULUS = 2.9E+7  FLOW STRESS = 93300

CONVERTING THIS DATA TO METRIC UNITS (mm.N.KPa) FOR: HY80-5B
WIDTH = 24.05126          NOTCH LENGTH = 11.2776
Bmax = 12.5984       Bmin = 10.0076
YIELD STRENGTH = 597085.603738   ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497E+8   FLOW STRESS = 643280.448369

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .444 in
OPTIMUN CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .12414 in
CRACK LENGTH AT 50% OF EXTENSION = .50607 in
Pmax = 3272.42651647 Lbs  Pmin = 163.621325823 Lbs
Delp = 3108.80519064 Lbs  Kmax = 82563.7466931
DELTA_K = 78435.5593585 in^.5  DELTA_KE = 40000 in^.5

NEW LOADS  BASED ON DELTA_KE ARE:
Pmax = 1668.84843723 Lbs  Pmin = 83.4424218615 Lbs
DELTA_P = 1585.40601537 Lbs   Kmax = 42105.2631579


       CONVERSION DATA
FOR LOAD  1779.288646 N/V   (-400 Lbs/V)
FOR COD  .0508 mm/V   ( .002 in/V)
FOR DEFLECTION:-12.7 mm/V   (-.5 in/V)
U = .07
a/W = .732186117982 in  CRACK LENGTH = .693307035117 in
```

LOAD (lbs)	COD (in)	COD (Volts)
200	.00256290169302	1.28145084651
300	.00384435253953	1.92217626976
400	.00512580338604	2.56290169302
500	.00640725423255	3.20362711627
600	.00768870507906	3.84435253953
700	.00897015592557	4.48507796278
800	.0102516067721	5.12580338604
900	.0115330576186	5.76652880929
1000	.0128145084651	6.40725423255
1100	.0140959593116	7.0479796558
1200	.0153774101581	7.68870507906
1300	.0166588610046	8.32943050231
1400	.0179403118511	8.97015592557
1500	.0192217626976	9.61088134882
1600	.0205032135441	10.2516067721
1700	.0217846643907	10.8923321953
1800	.0230661152372	11.5330576186

```
U = .075
a/W = .713968763392 in  CRACK LENGTH = .676057022056 in
```

LOAD (lbs)	COD (in)	COD (Volts)
200	.00220863052208	1.10431526104
300	.00331294578312	1.65647289156
400	.00441726104416	2.20863052208
500	.00552157630521	2.76078815260

USING ENGLISH UNITS (in,lbs,psi) THE FOLLOWING INFORMATION
HAS BEEN ENTERED FOR: HY80-5B

WIDTH = .9469 NOTCH LENGTH = .444
Bmax = .496 Bmin = .394
HALF SPAN = 1.394 POISSON'S RATIO = .3
YIELD STRENGTH = 86600 ULTIMATE TS = 100000
ELASTIC MODULUS = 2.9E+7 FLOW STRESS = 93300

CONVERTING THIS DATA TO METRIC UNITS (mm,N,KPa) FOR: HY80-5B
WIDTH = 24.05125 NOTCH LENGTH = 11.2776
Bmax = 12.5984 Bmin = 10.0076
YIELD STRENGTH = 597085.603738 ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497E+8 FLOW STRESS = 643280.448263

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .444 in
OPTIMUN CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .12414 in
CRACK LENGTH AT 50% OF EXTENSION = .50607 in
Pmax = 3272.42551647 Lbs Pmin = 163.621325823 Lbs
Delp = 3108.80519064 Lbs Kmax = 82563.7466331
DELTA_K = 78435.5593585 in^.5 DELTA_KE = 40000 in^.5

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1668.84843723 Lbs Pmin = 83.4424218615 Lbs
DELTA_P = 1585.40601537 Lbs Kmax = 42105.2631579

CONVERSION DATA
FOR LOAD:-1779.288646 N/V (-400 Lbs/V)
FOR COD: .0508 mm/V (.002 in/V)
FOR DEFLECTION:-12.7 mm/V (-.5 in/V)

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .477215195165 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .47792545403 TO .476507410981 in
USING COD COMPLIANCE OF: 2.84104311054E-6 in/Lb = 1.62905173472E-5 mm/N
WITH A CORRELATION OF: .999771386472 FROM 106 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .477198279382 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .478004054454 TO .476336178981 in
USING COD COMPLIANCE OF: 2.84076125094E-6 in/Lb = 1.63037750213E-5 mm/N
WITH A CORRELATION OF: .99959257929 FROM 124 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

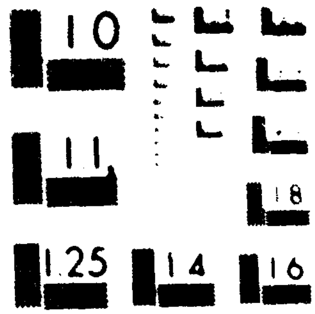
CURRENT CRACK LENGTH = .477198279382 in
OPTIMUN CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0909417206182 in
CRACK LENGTH AT 50% OF EXTENSION = .489470860309 in
Pmax = 2854.63728597 Lbs Pmin = 142.731864298 Lbs
Delp = 2711.90542167 Lbs Kmax = 80310.2753096
DELTA_K = 76294.7615441 in^.5 DELTA_KE = 40000 in .5

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 1496.63606161 Lbs Pmin = 74.8318030804 Lbs
DELTA_P = 1421.80425853 Lbs Kmax = 42105.2631579

AD-A142 033 ELASTIC-PLASTIC FRACTURE TOUGHNESS TESTING METHODS(U) 2/2
NAVAL POSTGRADUATE SCHOOL MONTEREY CA W K TRITCHLER
DEC 83

UNCLASSIFIED F/G 20/11 NL

END
DATE
FILMED
7-84
DTIC


1.0
1.1
1.8
1.25
1.4
1.6

[illegible]

NEW LOADS BASED ON DELTA KE ARE
Pmax = 1003.9351936 Lbs Pmin = 50.1967596798 Lbs
DELTA_P = 953.738433917 Lbs   Kmax = 30526.3157895

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .523238225069 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .524952826657 TO .521538109085 in
USING COD COMPLIANCE OF: 3.74604099481E-6 in/Lb = 2.16181567648E-5 mm/N
WITH A CORRELATION OF: .999183456903 FROM 61 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .519260644793 in FROM MEASUREMENT # 2

[illegible]

[illegible]

[illegible]

CURRENT CRACK LENGTH = [illegible] in
OPTIMUN CRACK LENGTH = [illegible] in
EXTENSION REQUIRED = [illegible] in
CRACK LENGTH AT 50% OF EXTENSION = [illegible] in
Pmax = 942.5[illegible] Lbs Pmin = 4[illegible] Lbs
Delp = 895.[illegible] Lbs Kmax = 3083[illegible]
DELTA_K = 29290.08[illegible] in^.5 DELTA_KE = 29000 in^.5

NEW LOADS BASED ON DELTA_KE ARE:
Pmax = 933.170289649 Lbs Pmin = 46.6585144825 Lbs
DELTA_P = 886.511775167 Lbs Kmax = 30526.3157895

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .557542180253 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .559342565208 TO .555757596687 in
USING COD COMPLIANCE OF: 4.6522934609E-6 in/Lb = 2.6877228564E-5 mm/N
WITH A CORRELATION OF: .999026349545 FROM 60 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .556985314799 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .559603140017 TO .554400760935 in
USING COD COMPLIANCE OF: 4.63555555373E-6 in/Lb = 2.69227537518E-5 mm/N
WITH A CORRELATION OF: .998286279816 FROM 51 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .55746232304 in FROM MEASUREMENT # 3
WITH 95%CONFIDENCE INTERVAL FROM .558944733365 TO .555990641885 in
USING COD COMPLIANCE OF: 4.64988856512E-6 in/Lb = 2.68079074153E-5 mm/N
WITH A CORRELATION OF: .999219985095 FROM 70 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .55746232304 in
OPTIMUN CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .0106776769602 in
CRACK LENGTH AT 50% OF EXTENSION = .44933883848 in
Pmax = 784.95101444 Lbs Pmin = 39.247550722 Lbs
Delp = 745.703463718 Lbs Kmax = 29594.1425953
DELTA_K = 28114.4354655 in^.5 DELTA_KE = 29000 in^.5

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .556873246958 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .558630143876 TO .555131398279 in
USING COD COMPLIANCE OF: 4.63219612139E-6 in/Lb = 2.67532481877E-5 mm/N

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .562208107534 in FROM MEASUREMENT # [illegible]
WITH 95%CONFIDENCE INTERVAL FROM .56343540602 TO .560988130658 in
USING COD COMPLIANCE OF: 4.79552996551E-6 in/Lb = 2.76035025025E-5 mm/N
WITH A CORRELATION OF: .999481124671 FROM 67 DATA POINTS.

BASED ON CURRENT INFORMATION FOR HY80-5B:

CURRENT CRACK LENGTH = .562208107534 in
OPTIMUN CRACK LENGTH = .56814 in
EXTENSION REQUIRED = .00593139246594 in
CRACK LENGTH AT 50% OF EXTENSION = .446965946233 in
Pmax = 765.336366326 Lbs Pmin = 38.2968183163 Lbs
Delp = 727.63954801 Lbs Kmax = 29428.399829
DELTA_K = 27957.4548376 in .5 DELTA_KE = 29000 in^.5

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .564151471472 in FROM MEASUREMENT # 1
WITH 95%CONFIDENCE INTERVAL FROM .565674835605 TO .562639453926 in
USING COD COMPLIANCE OF: 4.85680462792E-6 in/Lb = 2.80112437379E-5 mm/N
WITH A CORRELATION OF: .999133273453 FROM 72 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
CRACK LENGTH = .568361917225 in FROM MEASUREMENT # 2
WITH 95%CONFIDENCE INTERVAL FROM .569305393318 TO .567422811142 in
USING COD COMPLIANCE OF: 4.99294827909E-6 in/Lb = 2.86883916896E-5 mm/N
WITH A CORRELATION OF: .999601697254 FROM 84 DATA POINTS.

PRECRACKING IS COMPLETED!

FINAL CRACK LENGTH = .568361917225
CORRELATION OF DATA = .999601697254

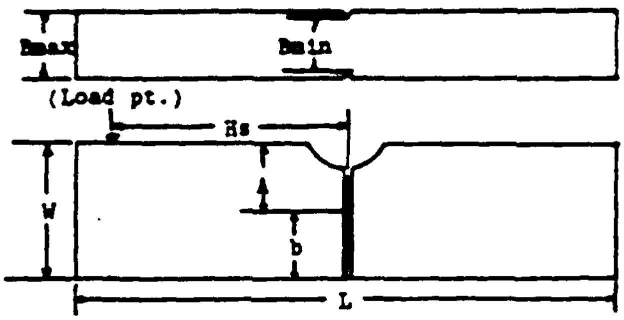
REMOVE SPECIMEN FROM MTS.

THREE POINT BEND SPECIMEN

TEST REPORT

SPECIMEN I.D. [illegible]-5A MATERIAL [illegible] ORIENTATION [illegible]

Date 12/13/83 Operator [illegible] Test Temp [illegible]



W = 0.9469" A = 0.444" b = 0.5029" L = 4.5"

Hs = 1.894" Bmax = 0.4960" Bmin = 0.394"

Ys = 86600 psi Uts = 100000 psi Fs = 93300 psi

Poisson's ratio = 0.3 Elastic Modulus = 2.9×10⁷ psi

Comments:

HY80 BASE METAL FROM PREHEATED WELD

PRECRACKED ON 12/11/83; J-TEST ON 12/13/83 ⇒ J_{Ic} = 142 KJ/m²

```
[illegible]
[illegible]

[illegible]
[illegible]
HALF SPAN = [illegible]   POISSON'S RATIO = [illegible]
YIELD STRENGTH = [illegible]   ULTIMATE TS = [illegible]
ELASTIC MODULUS = [illegible]   FLOW STRESS = [illegible]

CONVERTING THIS DATA TO METRIC UNITS [illegible]
WIDTH = [illegible]   NOTCH LENGTH = [illegible]
Bmax = [illegible] 3904   Bmin = [illegible]
HALF SPAN = 44 [illegible]   POISSON'S RATIO = [illegible]
YIELD STRENGTH = 597385.603778   ULTIMATE TS = 689475.293
ELASTIC MODULUS = 1.9994783497[illegible]E+8   FLOW STRESS = 643280.448369


        CONVERSION DATA
FOR LOAD:-1779.288646 N/V   ( 400 Lbs/V)
FOR COD: .254 mm/V   ( .01 in/V)
FOR DEFLECTION:-1.27 mm/V   ( .05 in/V)

GIVEN a= .568 inches THEN:
   Pmax= 895.290182804 Lbs FROM ASTM E813-81

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
INITIAL CRACK LENGTH = 14.3875382557 mm FROM MEASUREMENT # 1
WITH 95% CONFIDENCE INTERVAL FROM 14.4079726404  TO 14.3671845862 mm
USING COD COMPLIANCE OF: 2.81520064535E-5 mm/N
WITH A CORRELATION OF: .999323843963 FROM 189 DATA POINTS.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED:
INITIAL CRACK LENGTH = 14.4326755548 mm FROM MEASUREMENT # 2
WITH 95% CONFIDENCE INTERVAL FROM 14.4442813846  TO 14.42109582 mm
USING COD COMPLIANCE OF: 2.84829954475E-5 mm/N
WITH A CORRELATION OF: .99984474937 FROM 134 DATA POINTS.
```

[illegible]

[illegible]

CRACK LENGTH = [illegible] mm DELTA _a = [illegible] mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM [illegible] TO [illegible]

TOTAL # DATA POINTS = [illegible] # DATA POINTS THIS UNLOADING = [illegible]
CORRELATION = [illegible]
COD COMPLIANCE = [illegible] mm/N

AREA = [illegible] N*mm
J = 14.004980650[illegible] KJ/m^2
MAX LOAD LINE DEFLECTION = .24034834255 mm
CHANGE IN COD = .00109982 mm

---- UNLOADING # 2 ----

CRACK LENGTH = 14.4711513219 mm DELTA _a = .0384757670308 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.4927078135 TO 14.4496847244

TOTAL # DATA POINTS = 947 # DATA POINTS THIS UNLOADING = 132
CORRELATION = .999467111958
COD COMPLIANCE = 2.89307913363E-5 mm/N

AREA = 1693.69098454 N*mm
J = 35.2970225265 KJ/m^2
MAX LOAD LINE DEFLECTION = .382347556072 mm
CHANGE IN COD = .0008382 mm

---- UNLOADING # 3 ----

CRACK LENGTH = 14.4875164202 mm DELTA _a = .0548408654168 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.5143346851 TO 14.460837178

TOTAL # DATA POINTS = 1300 # DATA POINTS THIS UNLOADING = 157
CORRELATION = .999017363069
COD COMPLIANCE = 2.90942709989E-5 mm/N

AREA = 3033.0003923 N*mm
J = 63.28381022 KJ/m^2
MAX LOAD LINE DEFLECTION = .543433314464 mm
CHANGE IN COD = .0009398 mm

---- UNLOADING # 4 ----

CRACK LENGTH = 14.5414951598 mm DELTA _a = .108819604992 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.5601316376 TO 14.5229259715

TOTAL # DATA POINTS = 1670 # DATA POINTS THIS UNLOADING = 109
CORRELATION = .999675611283
COD COMPLIANCE = 2.94442988118E-5 mm/N

AREA = 5208.32927275 N*mm
J = 108.998439815 KJ/m^2
MAX LOAD LINE DEFLECTION = .782918890293 mm

[illegible]

[illegible]

[illegible]
[illegible]

[illegible]
[illegible]
[illegible]

AREA = [illegible] N*mm
J = 169.[illegible] KJ/m^2
MAX LOAD LINE DEFLECTION = [illegible]0455056629 mm
CHANGE IN COD = .0008636 mm

---- UNLOADING # 6 ----

CRACK LENGTH = 14.8152586049 mm   DELTA _a = .382583050059 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.8481840789 TO 14.782543466

TOTAL # DATA POINTS = 2280   # DATA POINTS THIS UNLOADING = 138
CORRELATION = .998642018089
COD COMPLIANCE = 3.17719219461E-5 mm/N

AREA = 9001.97373669 N*mm
J = 185.342172083 KJ/m^2
MAX LOAD LINE DEFLECTION = 1.18989063161 mm
CHANGE IN COD = .0009906 mm

---- UNLOADING # 7 ----

CRACK LENGTH = 14.8695206824 mm   DELTA _a = .436845127588 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 14.8849566722 TO 14.8541311238

TOTAL # DATA POINTS = 2531   # DATA POINTS THIS UNLOADING = 147
CORRELATION = .999677856393
COD COMPLIANCE = 3.20855798284E-5 mm/N

AREA = 9678.11102926 N*mm
J = 198.876552682 KJ/m^2
MAX LOAD LINE DEFLECTION = 1.26297067275 mm
CHANGE IN COD = .0004572 mm

---- UNLOADING # 8 ----

CRACK LENGTH = 15.0148445285 mm   DELTA _a = .582168973634 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.0416778385 TO 14.9881516089

TOTAL # DATA POINTS = 2761   # DATA POINTS THIS UNLOADING = 97
CORRELATION = .999364204197
COD COMPLIANCE = 3.34673392487E-5 mm/N

AREA = 10586.6765231 N*mm
J = 215.448776655 KJ/m^2
MAX LOAD LINE DEFLECTION = 1.36396114491 mm

[illegible]

[illegible]

[illegible]
[illegible]

TOTAL # DATA POINTS = [illegible]   # DATA POINTS THIS UNLOADING = [illegible]
CORRELATION = [illegible]
COD COMPLIANCE = [illegible]

AREA = [illegible] N*mm
J = [illegible] KJ/m^2
MAX LOAD LINE DEFLECTION = 1.49020183752 mm
CHANGE IN COD = [illegible] mm

---- UNLOADING # 10 ----

CRACK LENGTH = 15.2624877891 mm   DELTA _a = .829812234314 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.2760292626 TO 15.2489823604

TOTAL # DATA POINTS = 3394   # DATA POINTS THIS UNLOADING = 167
CORRELATION = .999700915055
COD COMPLIANCE = 3.56785340653E-5 mm/N

AREA = 12983.4083914 N*mm
J = 262.394826944 KJ/m^2
MAX LOAD LINE DEFLECTION = 1.63760345064 mm
CHANGE IN COD = .0007366 mm

---- UNLOADING # 11 ----

CRACK LENGTH = 15.3993548961 mm   DELTA _a = .966679341294 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.4107739959 TO 15.3879615278

TOTAL # DATA POINTS = 3867   # DATA POINTS THIS UNLOADING = 204
CORRELATION = .999734089719
COD COMPLIANCE = 3.70351235759E-5 mm/N

AREA = 14557.9277896 N*mm
J = 294.038000741 KJ/m^2
MAX LOAD LINE DEFLECTION = 1.82262379631 mm
CHANGE IN COD = .0004318 mm

---- UNLOADING # 12 ----

CRACK LENGTH = 15.669999544 mm   DELTA _a = 1.2373239892 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 15.6847004127 TO 15.6553416287

TOTAL # DATA POINTS = 4267   # DATA POINTS THIS UNLOADING = 154
CORRELATION = .999652892868
COD COMPLIANCE = 4.00050024785E-5 mm/N

AREA = 16330.4160222 N*mm
J = 325.442585526 KJ/m^2
MAX LOAD LINE DEFLECTION = 2.03825076401 mm

[illegible]

---- UNLOADING # [illegible] ----

[illegible]

[illegible]

AREA = [illegible] N*mm
J = 355.360006494 KJ/m^2
MAX LOAD LINE DEFLECTION = 2.242[illegible]3294335 mm
CHANGE IN COD = .000508 mm

---- UNLOADING # 14 ----

CRACK LENGTH = 16.1357477216 mm   DELTA _a = 1.7030721668 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.1463233402 TO 16.1251947229

TOTAL # DATA POINTS = 5206   # DATA POINTS THIS UNLOADING = 239
CORRELATION = .999696024845
COD COMPLIANCE = 4.57508725867E-5 mm/N

AREA = 19646.0705407 N*mm
J = 385.620902249 KJ/m^2
MAX LOAD LINE DEFLECTION = 2.47449867471 mm
CHANGE IN COD = .0004826 mm

---- UNLOADING # 15 ----

CRACK LENGTH = 16.4193583405 mm   DELTA _a = 1.98668278568 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.4364102869 TO 16.4023658462

TOTAL # DATA POINTS = 5648   # DATA POINTS THIS UNLOADING = 194
CORRELATION = .9993242 90353
COD COMPLIANCE = 4.99261698493E-5 mm/N

AREA = 21264.009056 N*mm
J = 412.083508069 KJ/m^2
MAX LOAD LINE DEFLECTION = 2.70365472703 mm
CHANGE IN COD = .0005334 mm

---- UNLOADING # 16 ----

CRACK LENGTH = 16.9028626935 mm   DELTA _a = 2.47018713865 mm
95% CONFIDENCE INTERVAL ON CRACK LENGTH IS FROM 16.9171173874 TO 16.888656585

TOTAL # DATA POINTS = 6102   # DATA POINTS THIS UNLOADING = 162
CORRELATION = .999564028818
COD COMPLIANCE = 5.80350094828E-5 mm/N

AREA = 22950.1834392 N*mm
J = 428.162914109 KJ/m^2
MAX LOAD LINE DEFLECTION = 2.96684800605 mm

[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

UNLOADING #	DELTA_a(mm)	J(kJ/m2)
1	.016075	[illegible]
2	.038476	35.3
3	.054841	63.3
4	.108820	109.0
5	.308074	169.9
6	.382583	185.3
7	.436845	198.9
8	.532169	215.4
9	.689001	237.7
10	.829812	262.4
11	.966679	294.0
12	1.237324	325.4
13	1.445466	355.4
14	1.703072	385.6
15	1.986683	412.1
16	2.470187	428.2

DATA FROM J vs DELTA_a PLOT

SLOPE = 164.148013927   Y-INTERCEPT = 123.923075018
CORRELATION = .99667195294   FROM 9 DATA POINTS.

Jlc = 142.05774949

TEST IS OVER!

[illegible]

```
FROM [illegible]

FROM COMPLIANCE = [illegible]

CORRELATION= [illegible] FROM [illegible] DATA POINTS

DO YOU WANT A HARD COPY OF THIS INFORMATION?
```

```
FROM UNLOADING # 1 RECORDED 128 DATA POINTS
COD COMPLIANCE = 2.87555293817E-5 mm/N   CORRELATION = .999529434569
CRACK LENGTH = 14.4487507815 mm   DELTA_A = .016075226716 mm
95% CONFIDENCE INTERVAL FROM 14.4693514291 mm TO 14.4282322251 mm
AREA = 711.365042717 N*mm   J = 14.8049806501 KPa*m
DATA POINT INDEXES FROM 504 TO 632  WERE USED.

FROM UNLOADING # 2 RECORDED 132 DATA POINTS
COD COMPLIANCE = 2.89307913363E-5 mm/N   CORRELATION = .999467111958
CRACK LENGTH = 14.4711513219 mm   DELTA_A = .0384757670308 mm
95% CONFIDENCE INTERVAL FROM 14.4927078135 mm TO 14.4496847244 mm
AREA = 1693.69098454 N*mm   J = 35.2970225265 KPa*m
DATA POINT INDEXES FROM 815 TO 947  WERE USED.

FROM UNLOADING # 3 RECORDED 157 DATA POINTS
COD COMPLIANCE = 2.90942709989E-5 mm/N   CORRELATION = .999017363069
CRACK LENGTH = 14.4875164202 mm   DELTA_A = .0548408654168 mm
95% CONFIDENCE INTERVAL FROM 14.5143346851 mm TO 14.460837178 mm
AREA = 3033.0003923 N*mm   J = 63.28381022 KPa*m
DATA POINT INDEXES FROM 1143 TO 1300  WERE USED.

FROM UNLOADING # 4 RECORDED 109 DATA POINTS
COD COMPLIANCE = 2.94442988118E-5 mm/N   CORRELATION = .999675611283
CRACK LENGTH = 14.5414951598 mm   DELTA_A = .108819604992 mm
95% CONFIDENCE INTERVAL FROM 14.5601316376 mm TO 14.5229259715 mm
AREA = 5208.32927275 N*mm   J = 108.998439815 KPa*m
DATA POINT INDEXES FROM 1561 TO 1670  WERE USED.

FROM UNLOADING # 5 RECORDED 95 DATA POINTS
COD COMPLIANCE = 3.10248861726E-5 mm/N   CORRELATION = .999731105207
```

[illegible]

[illegible]

[illegible]

```
FROM UNLOADING # 8 RECORDED [illegible] DATA POINTS
COD COMPLIANCE = 3.3467339[illegible]E-5 mm/N   CORRELATION = [illegible]
CRACK LENGTH = 15.0148445285 mm   DELTA_A = .58[illegible] mm
95% CONFIDENCE INTERVAL FROM 15.04[illegible] mm TO 14.988[illegible] mm
AREA = 10586.6765231 N*mm   J = 2[illegible]5.448[illegible]6655 KPa*m
DATA POINT INDEXES FROM 2664 TO 2761  WERE USED.

FROM UNLOADING # 9 RECORDED 119 DATA POINTS
COD COMPLIANCE = 3.43343078736E-5 mm/N   CORRELATION = .99977636544
CRACK LENGTH = 15.1216765395 mm   DELTA_A = .689000984704 mm
95% CONFIDENCE INTERVAL FROM 15.1358606[illegible] mm TO 15.1075318754 mm
AREA = 11709.4655627 N*mm   J = 237.699077286 KPa*m
DATA POINT INDEXES FROM 2923 TO 3042  WERE USED.

FROM UNLOADING # 10 RECORDED 167 DATA POINTS
COD COMPLIANCE = 3.56785340653E-5 mm/N   CORRELATION = .999700915055
CRACK LENGTH = 15.2624877891 mm   DELTA_A = .829812[illegible]34314 mm
95% CONFIDENCE INTERVAL FROM 15.2760292626 mm TO 15.2489823604 mm
AREA = 12983.4083914 N*mm   J = 262.394826944 KPa*m
DATA POINT INDEXES FROM 3227 TO 3394  WERE USED.

FROM UNLOADING # 11 RECORDED 204 DATA POINTS
COD COMPLIANCE = 3.70351235759E-5 mm/N   CORRELATION = .999734089719
CRACK LENGTH = 15.3993548961 mm   DELTA_A = .966679341294 mm
95% CONFIDENCE INTERVAL FROM 15.4107739959 mm TO 15.3879615278 mm
AREA = 14557.9277896 N*mm   J = 294.038000741 KPa*m
DATA POINT INDEXES FROM 3663 TO 3867  WERE USED.

FROM UNLOADING # 12 RECORDED 154 DATA POINTS
COD COMPLIANCE = 4.00050024785E-5 mm/N   CORRELATION = .999652892868
CRACK LENGTH = 15.669999544 mm   DELTA_A = 1.2373239892 mm
95% CONFIDENCE INTERVAL FROM 15.6847004127 mm TO 15.6553416287 mm
AREA = 16330.4160222 N*mm   J = 325.442585526 KPa*m
DATA POINT INDEXES FROM 4113 TO 4267  WERE USED.
```

```
FROM UNLOADING # 13 RECORDED 208 DATA POINTS
COD COMPLIANCE = 4.24377123766E-5 mm/N   CORRELATION = .999677232131
CRACK LENGTH = 15.8781418346 mm   DELTA_A = 1.44546627973 mm
95% CONFIDENCE INTERVAL FROM 15.8901071812 mm TO 15.8662051558 mm
AREA = 17933.7183158 N*mm   J = 355.360006494 KPa*m
DATA POINT INDEXES FROM 4502 TO 4710  WERE USED.

FROM UNLOADING # 14 RECORDED 239 DATA POINTS
COD COMPLIANCE = 4.57508725867E-5 mm/N   CORRELATION = .999696024845
CRACK LENGTH = 16.1357477216 mm   DELTA_A = 1.7030721668 mm
95% CONFIDENCE INTERVAL FROM 16.1463233402 mm TO 16.1251947229 mm
AREA = 19646.0705407 N*mm   J = 385.620902249 KPa*m
DATA POINT INDEXES FROM 4967 TO 5206  WERE USED.

FROM UNLOADING # 15 RECORDED 194 DATA POINTS
COD COMPLIANCE = 4.99261698493E-5 mm/N   CORRELATION = .999324290353
CRACK LENGTH = 16.4193583405 mm   DELTA_A = 1.98668278568 mm
95% CONFIDENCE INTERVAL FROM 16.4364102869 mm TO 16.4023658462 mm
AREA = 21264.009056 N*mm   J = 412.083508069 KPa*m
DATA POINT INDEXES FROM 5454 TO 5648  WERE USED.

FROM UNLOADING # 16 RECORDED 162 DATA POINTS
COD COMPLIANCE = 5.80350094828E-5 mm/N   CORRELATION = .999564028818
CRACK LENGTH = 16.9028626935 mm   DELTA_A = 2.47018713865 mm
95% CONFIDENCE INTERVAL FROM 16.9171113874 mm TO 16.888656585 mm
AREA = 22950.1834392 N*mm   J = 428.162914109 KPa*m
DATA POINT INDEXES FROM 5940 TO 6102  WERE USED.
```

DATA FROM aU FOR:HY80-3B BY: KURT

TESTED ON: 12-13-83 TIME: 10:35

PT #	LOAD (N)	DEFLECTION (mm)	COD (mm)
1	2262.5	.079424	.060576
2	2261.7	.074706	.060576
3	2265.2	.076740	.060637
4	2277.8	.079003	.061003
5	2350.8	.093469	.063589
6	2409.0	.094978	.065014
7	2442.3	.095627	.065895
8	2463.4	.096491	.066429
9	2478.9	.096968	.066954
10	2496.2	.097378	.067280
11	2505.2	.097666	.067627
12	2515.4	.098165	.067772
13	2526.1	.098554	.068207
14	2539.6	.099114	.068511
15	2554.0	.099864	.068969
16	2570.4	.100177	.069411
17	2595.3	.101411	.070231
18	2624.1	.102889	.071107
19	2653.4	.103775	.072045
20	2688.5	.104678	.072903
21	2722.7	.106054	.073863
22	2746.9	.106721	.074519
23	2764.1	.107052	.075024
24	2779.2	.108077	.075443
25	2799.9	.108725	.075956
26	2820.2	.109596	.076655
27	2837.8	.110482	.077142
28	2854.0	.110667	.077617
29	2873.4	.112035	.078313
30	2939.6	.114805	.080284
31	2984.9	.115696	.081471
∫∫	∫∫	∫∫	∫∫
6085	5686.4	2.954239	2.460422
6086	5692.7	2.954786	2.460701
6087	5699.1	2.955204	2.461209
6088	5704.9	2.955629	2.461616
6089	5716.5	2.956736	2.462454
6090	5731.8	2.957790	2.463394
6091	5747.5	2.959093	2.464359
6092	5761.2	2.959789	2.465172
6093	5768.6	2.960445	2.465730
6094	5777.0	2.961089	2.466442
6095	5785.5	2.961730	2.467051
6096	5792.8	2.962262	2.467534
6097	5803.0	2.963643	2.468321
6098	5812.6	2.964142	2.469007
6099	5818.6	2.964692	2.469540
6100	5824.1	2.965503	2.470175
6101	5830.0	2.965801	2.470582
6102	5836.8	2.966848	2.471293

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